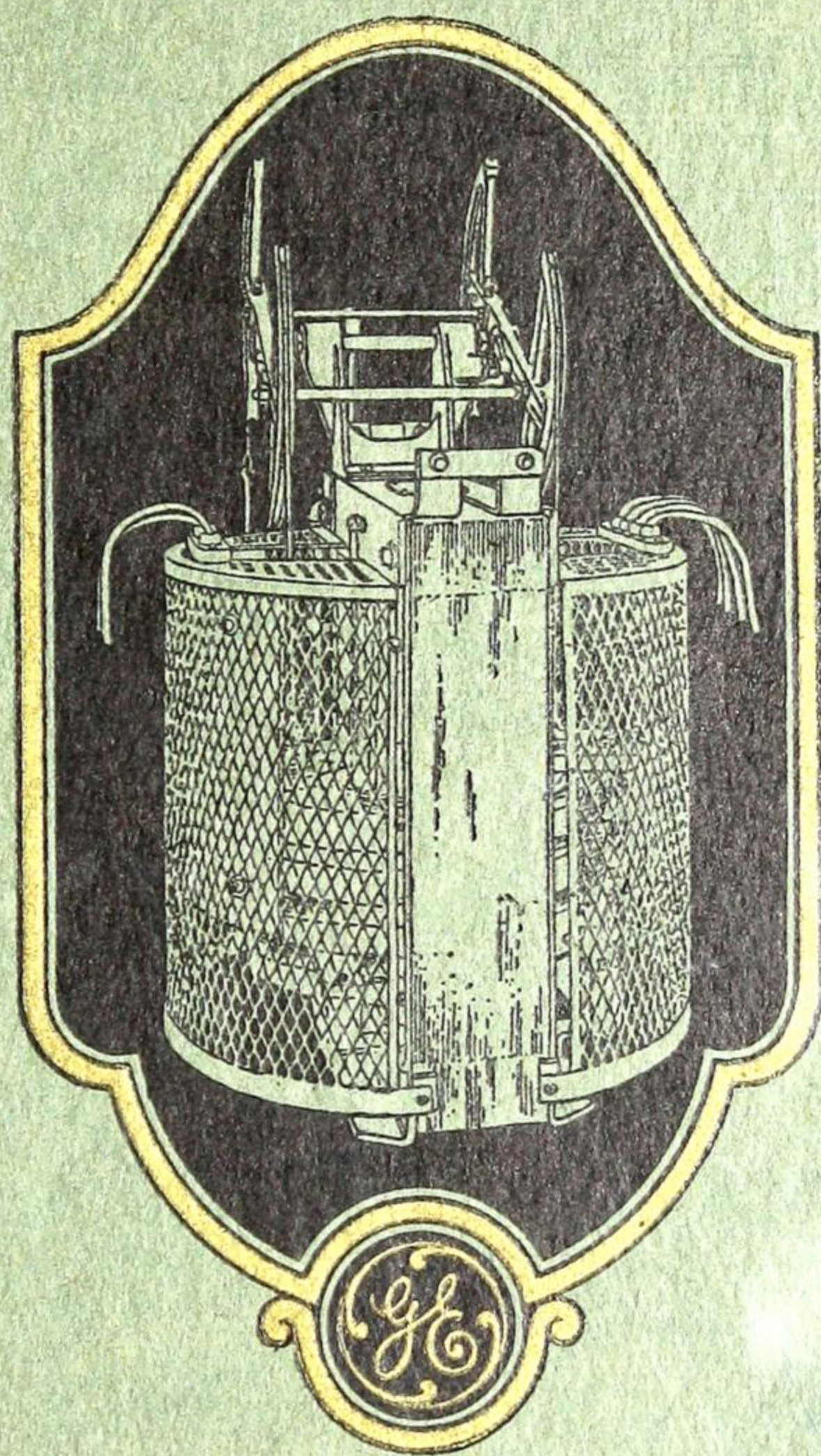


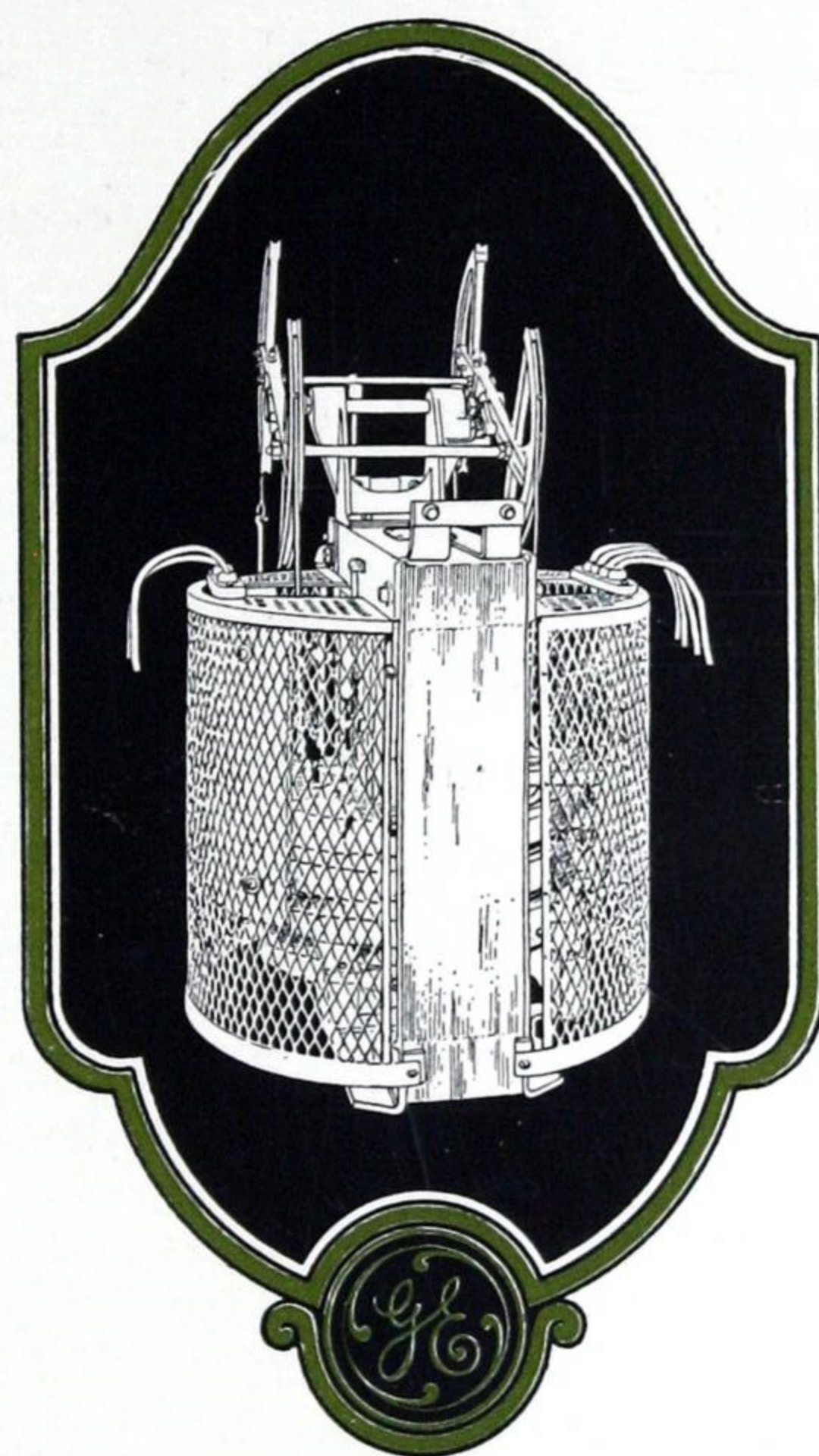
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STREET LIGHTING TRANSFORMERS



GENERAL ELECTRIC COMPANY

STREET LIGHTING TRANSFORMERS



GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y.

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Street Lighting Transformers

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INTRODUCTION

SERIES circuits have been used for electrical street lighting from an early date, when the old carbon arc lamps, which were inherently constant current devices, were the only light sources, and a constant current dynamo supplied the energy. The series system has remained in general use partly because such a widely distributed load as one of street lights is very difficult to control by any other system, and partly because of the high efficiency of series incandescent lamps and the low conductor losses of constant current circuits. Modern street lighting systems have discarded the old arc generator in favor of the constant current transformer and the old carbon arc lamps for the MAZDA C lamp and the luminous arcs; at the same time 6.6 amperes has become the accepted standard value for constant current in series lighting circuits.

Because of the very general adoption of the series circuit for street lighting, "constant current" and "street lighting" have become almost synonymous in transformer parlance. In fact, the series transformers, like series incandescent lamps, highly insulated receptacles, parkway cable, short circuiting protective devices and other equipment are designed entirely for street lighting service.

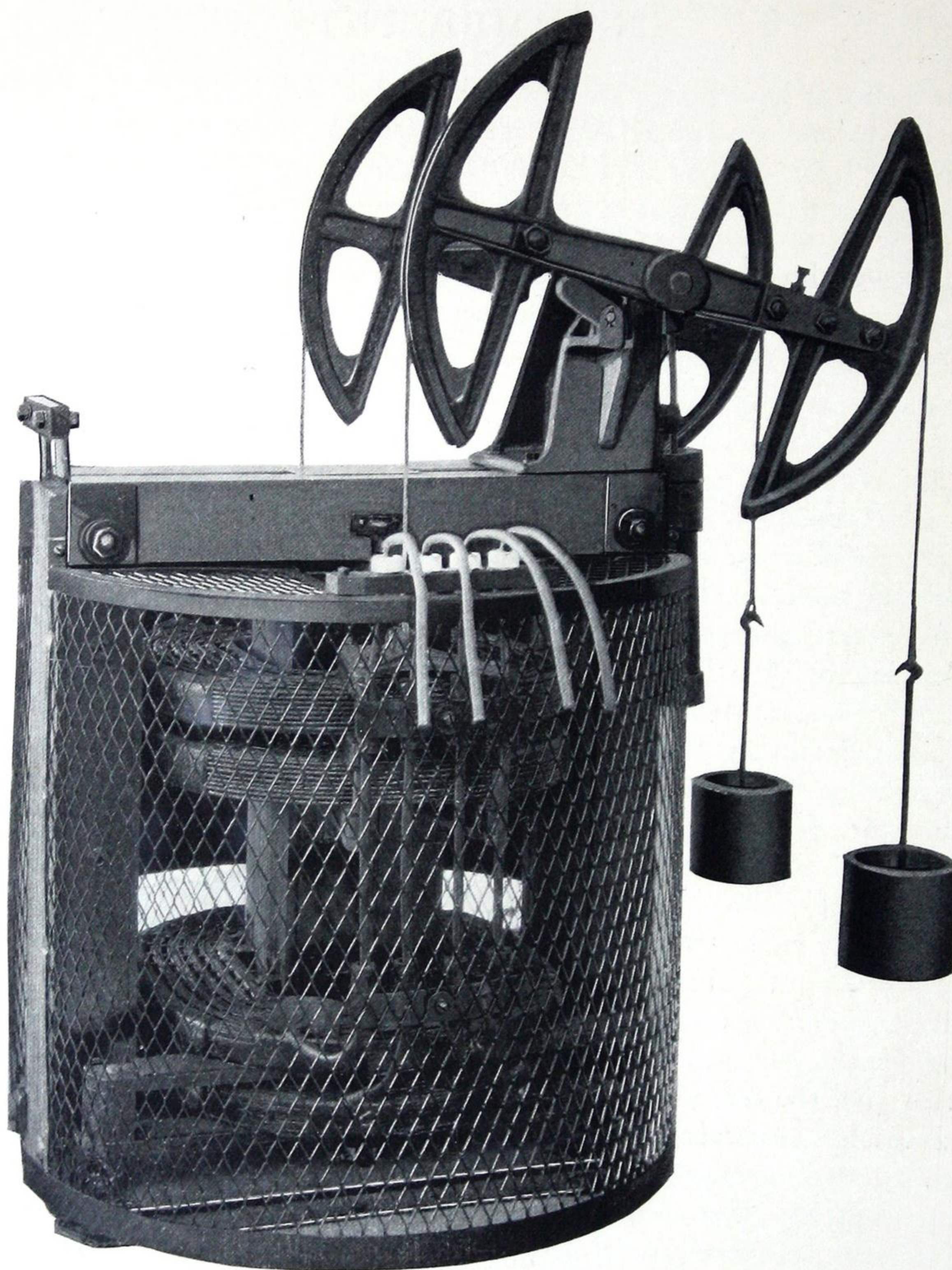
Regulating transformers receive energy at constant potential and deliver it at constant current. Such transformers have a movable coil, the position of which changes automatically with the load to maintain constant current. Good regulation is absolutely essential in these transformers when they are used with incandescent lamps; without it, the intensity of the lamps and their life may vary greatly from normal. General Electric current regulating transformers will all maintain the current within *one per cent* of rated value from full load to dead short circuit.

The auxiliary series transformers are designed to step up the current for use with high efficiency lamps, to insulate a subsidiary circuit, or to do both.

All the General Electric street lighting transformers are carefully tested and inspected before they are shipped from the factory. The constant current regulating transformers are adjusted to give the correct current and the best regulation. The series transformers are all tested for correctness of ratio. Voltage tests equal to or greater than those prescribed by the American Institute of Electrical Engineers are given all transformers.

No attempt has been made in this bulletin to explain the theory of operation of constant current transformers; to give dimensions, weights, and special ratings; or to describe completely control equipment. Auto-transformers, which are a part of ornamental lighting units, and constant current transformers used with mercury arc rectifiers for luminous arc systems are omitted because of the very limited nature of their applications.

For complete information regarding dimensions, weights, prices and so forth, of street lighting transformers as well as for data on transformers and control equipment for voltages, frequencies, and currents other than those described, one of the offices of the General Electric Company should be consulted.



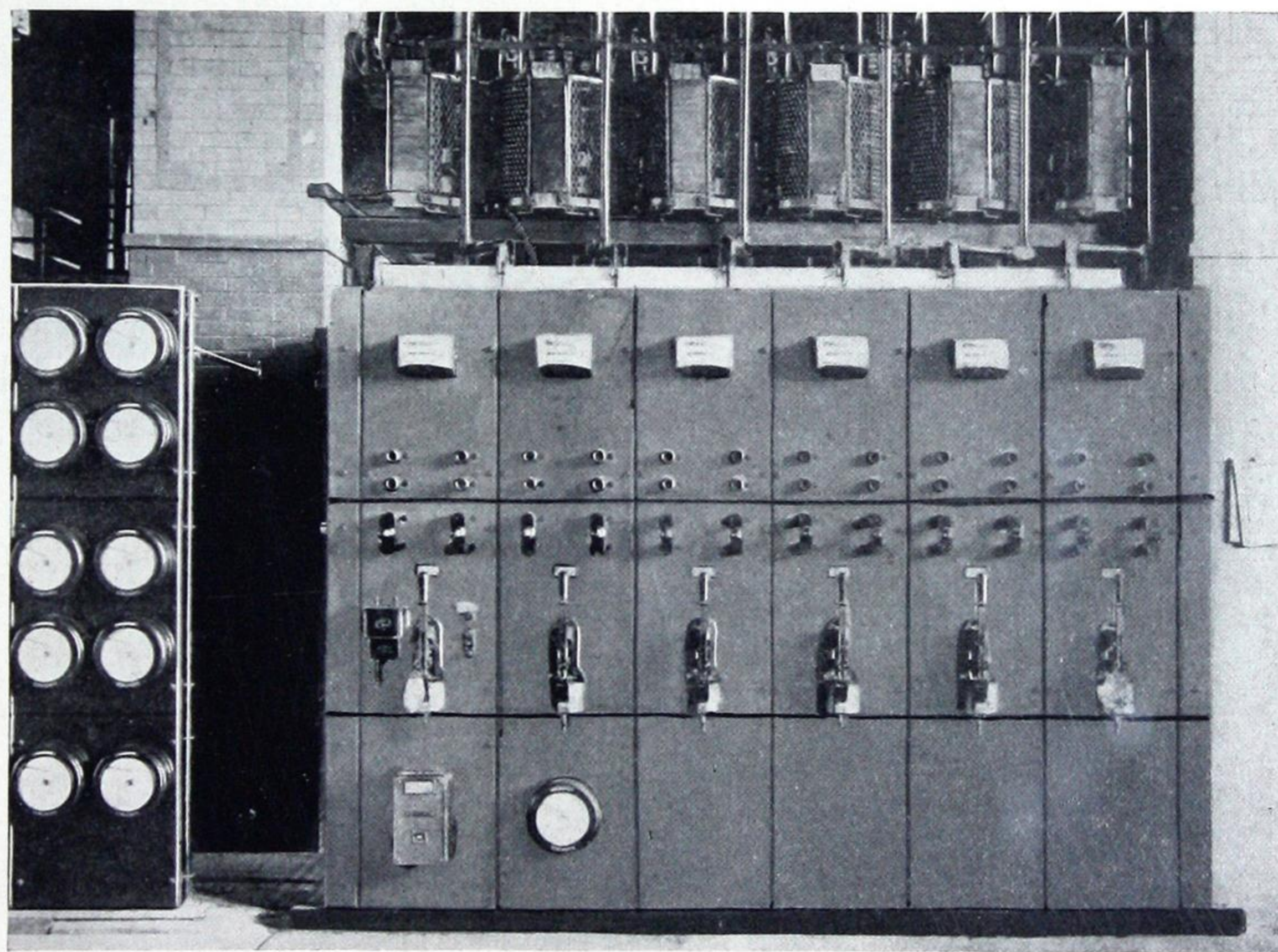
TYPE RV TRANSFORMER

A non-automatic, station type, constant current, regulating transformer for feeding series street lighting circuits

STATION TYPE CONSTANT CURRENT TRANSFORMER, TYPE RV

THE Type RV constant current transformers are intended for use in central stations or substations where an operator is in attendance. They are built in sizes ranging from 5 to 70 kilowatts output, for any commercial secondary current or primary frequency, or for any primary potential up to and including 13,200 volts. Most of these transformers are designed for 60 cycles, 2300 volts on the primary and 6.6 amperes on the secondary because these are by far the most common voltages and currents used.

Of primary importance in any transformer supplying series circuits is the regulation of the secondary current; since series incandescent lamps, when operated slightly above



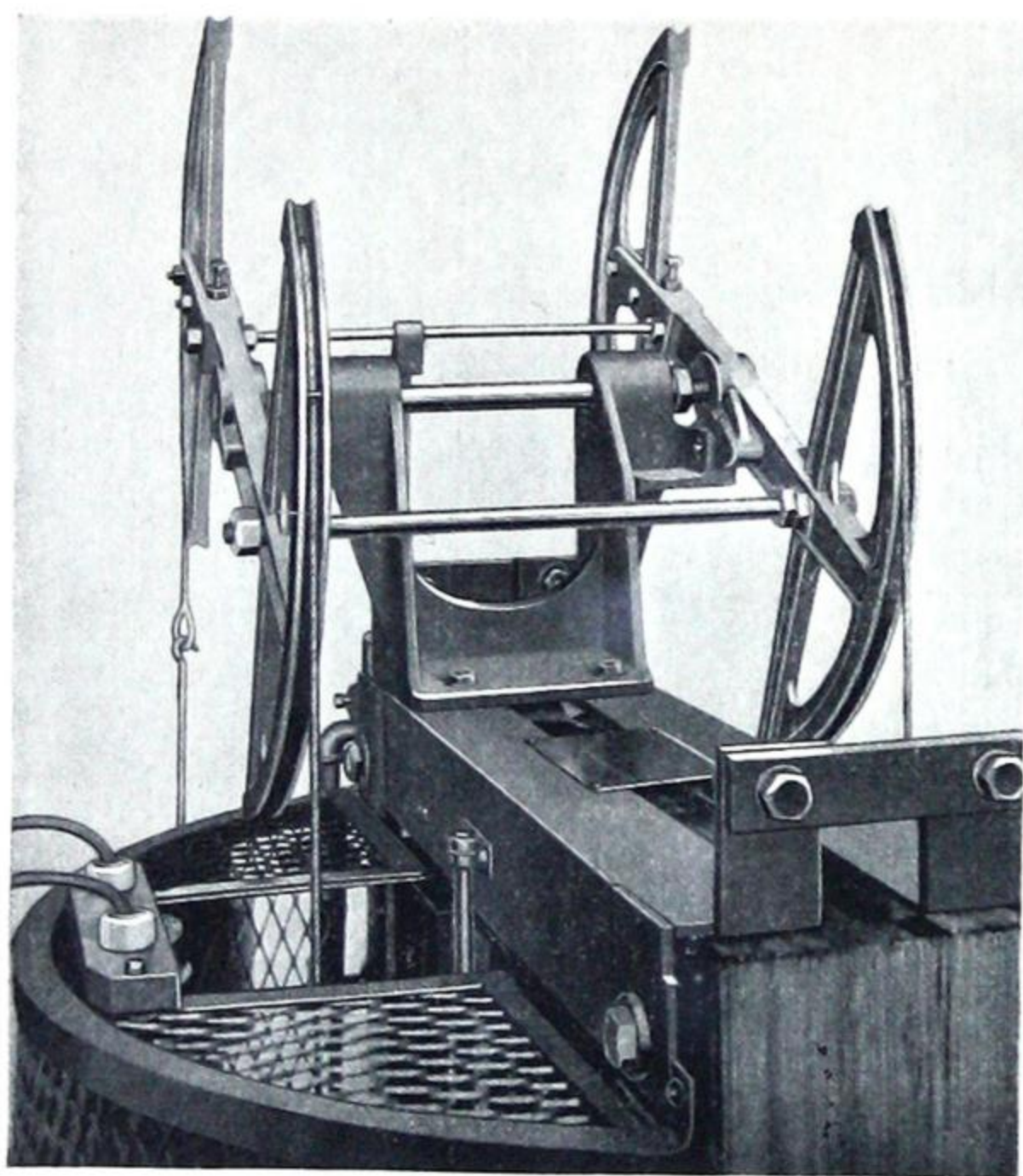
An installation of Type RV Transformers with control panels

normal current, have greatly shortened life, and if below normal current, give much less light than they normally should. The exceptionally fine regulation of General Electric constant current transformers which insures rated lumen output and full life of lamps, is one of their best recommendations.

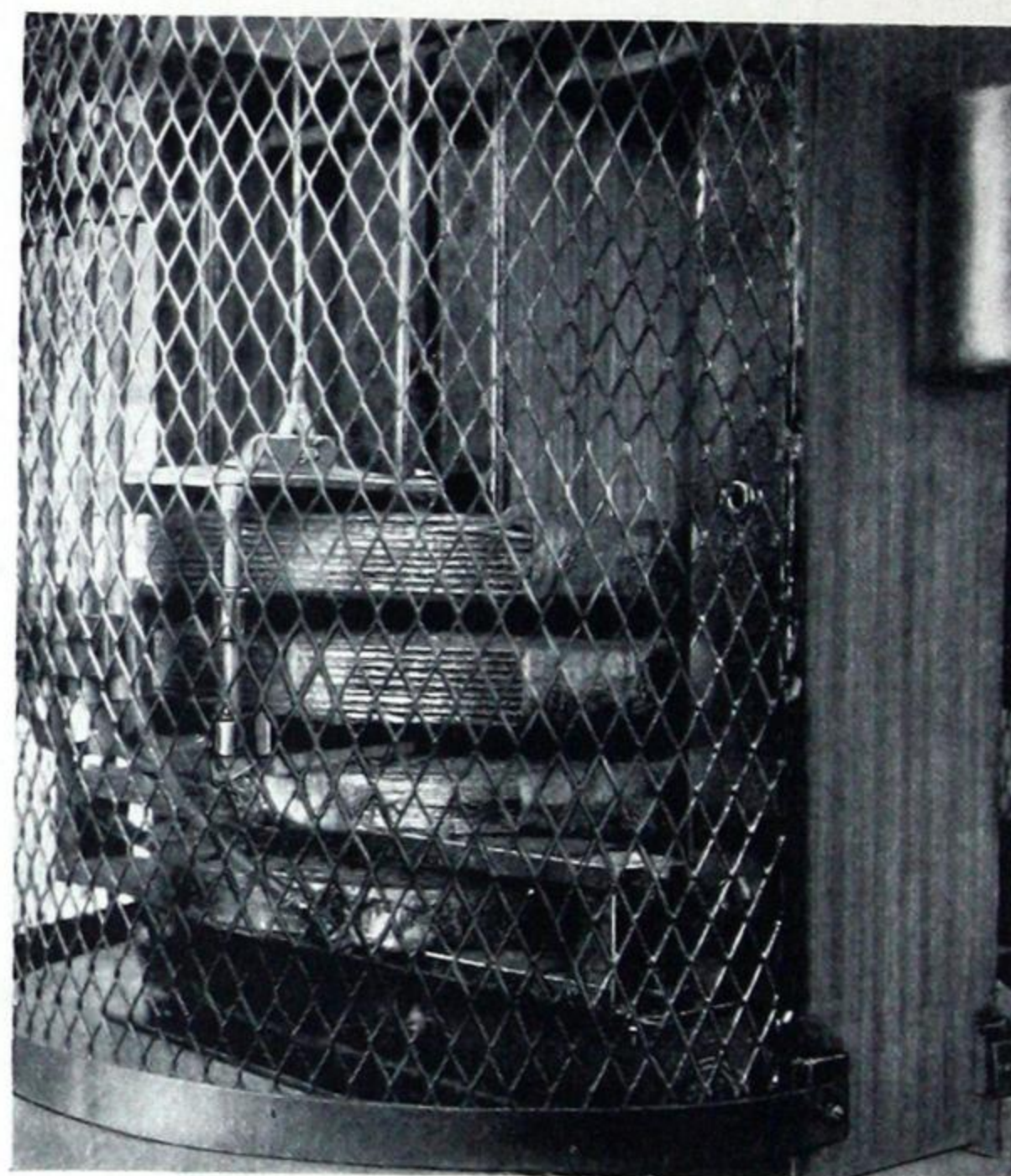
The Type RV constant current transformer will maintain the secondary current within *one per cent* of normal from full load to short circuit, provided, of course, that the primary potential and frequency remain constant. This excellent regulation is obtained

only through careful attention to design and construction. Light weight moving parts make the response to changes in load rapid and certain. Ball bearings on the rocker arm eliminate friction. Flexible steel supporting cables and flexible leads to the moving coil insure smooth operation and permanent adjustment. These mechanical details together with high magnetic repulsion give the close regulation necessary for successful operation of series lighting systems.

The Type RV transformer is air cooled. The windings are subdivided, having vertical ventilating ducts. The coils and core are surrounded by an expanded metal casing which allows free circulation of air and yet prevents accidental contact with live parts or interference with the moving coil. This screen may be removed easily for cleaning purposes but should always be used when the transformer is in operation. Transformers are designed to have an ultimate temperature rise not to exceed 55 degrees centigrade by resistance based on a surrounding air temperature of 25 degrees centigrade.



The rocker arms are mounted on ball bearings, and are rigidly braced by crossrods. The rear rocker arms are adjustable. Steel pins across the grooves prevent the suspension cables from jumping out



The core is held together by tubular brass rivets and the coils are strongly braced. This insures quiet operation and reduces the likelihood of parts coming loose through vibration

A dashpot of ample size to prevent swinging is regularly supplied with each transformer.

The core is built of laminations held together by tubular brass rivets. This riveted construction reduces vibration and produces quiet operation. The coils are clamped between textoil braces which make an almost unbreakable construction. The rocker arms are substantially constructed and securely braced to withstand mechanical shocks during line surges. An angle iron framework is used.

The transformer is adjusted at the factory to deliver constant rated current and it should be unnecessary to change these adjustments.

Adjustments when necessary are made by altering the position of the rocker arms and by increasing or decreasing the weights which counterbalance the moving coils. In starting the Type RV transformers, the coil must be latched apart till the load is on, after which the moving coil should be unlatched provided it has not done so automatically.

The output rating of the Type RV transformers is based on a unity power-factor load, i.e., straight resistance such as incandescent lamps without transformers. In order to compensate for ohmic and reactive losses in the load circuit and fluctuations of the voltage or frequency in the supply circuit, all of these transformers have 10 per cent additional load carrying capacity over their normal kilowatt rating. A light load tap is provided in the primary winding of all Type RV transformers to permit operation at 80 per cent maximum

GENERAL DATA ON THE TYPE RV TRANSFORMER

*Transformer Output in Kilowatts at Unity Power-factor Load	Primary Input Kv-a.	SECONDARY VOLTAGE		† EFFICIENCIES			† PRIMARY POWER-FACTORS			Net Weight Pounds
		Full Load	Open Circuit	100 Per Cent Load	75 Per Cent Load	50 Per Cent Load	100 Per Cent Load	75 Per Cent Load	50 Per Cent Load	
5	6.17	758	910	95.25	94.50	92.25	92.50	84.25	57.0	300
10	12.30	1515	1820	96.00	95.25	93.25	92.50	83.50	56.5	475
15	18.45	2275	2725	96.25	95.50	94.25	92.00	83.25	56.25	650
20	24.61	3030	3640	96.50	96.00	94.75	92.00	82.75	56.0	800
25	30.80	3790	4550	96.50	96.00	95.00	91.50	82.00	54.5	1050
30	37.00	4550	5455	96.75	96.25	95.25	91.25	82.00	54.5	1250
†35	43.10	5300	6365	96.75	96.25	95.25	91.25	82.00	54.5	1300
†40	49.25	6060	7275	97.00	96.50	95.50	91.25	82.00	54.5	1350
†50	61.50	7580	9100	97.00	96.50	95.50	91.25	82.00	54.5	1550
†60	73.90	9100	10910	97.25	96.75	95.75	91.25	82.00	54.5	1800
†70	86.20	10600	12750	97.25	96.75	95.75	91.25	82.00	54.5	2100

* In order to compensate for ohmic and reactive losses in the load circuit and fluctuations of voltage or frequency in the supply circuit, all of these transformers have ten per cent additional load carrying capacity over their normal kilowatt output rating.

† Figures on efficiency and power-factor at seventy-five and fifty per cent load are based on using the eighty per cent load connection.

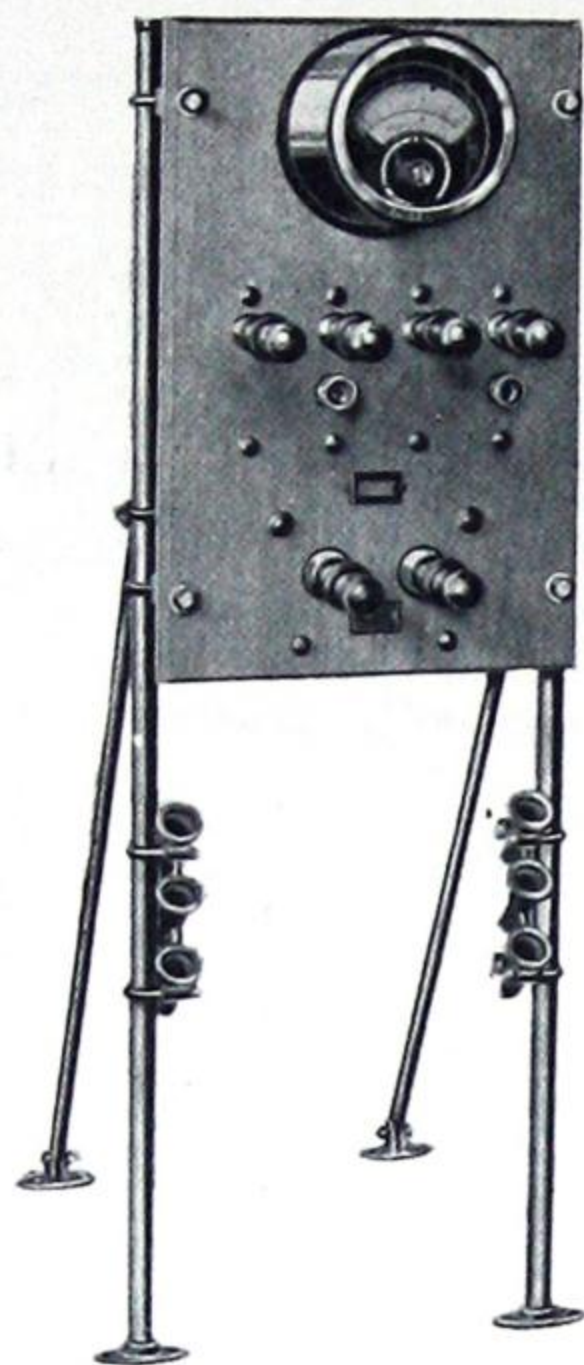
‡ These transformers are built with multi-circuit secondaries but can be operated as single-circuit if desired

The data included in this table are for the standard 2300-volt, 60-cycle, 6.6-ampere transformer.

load while retaining full load operating characteristics. Transformers of 35 kilowatts and above are also built with multi-circuit secondaries which can be operated single-circuit if desired.

Finally it should be kept in mind that the design and materials used in the construction of General Electric street lighting transformers are the result of research and experience obtained in the development of electrical equipment over a period covering the entire life of the industry.

CONTROL AND PROTECTIVE DEVICES FOR THE TYPE RV TRANSFORMER



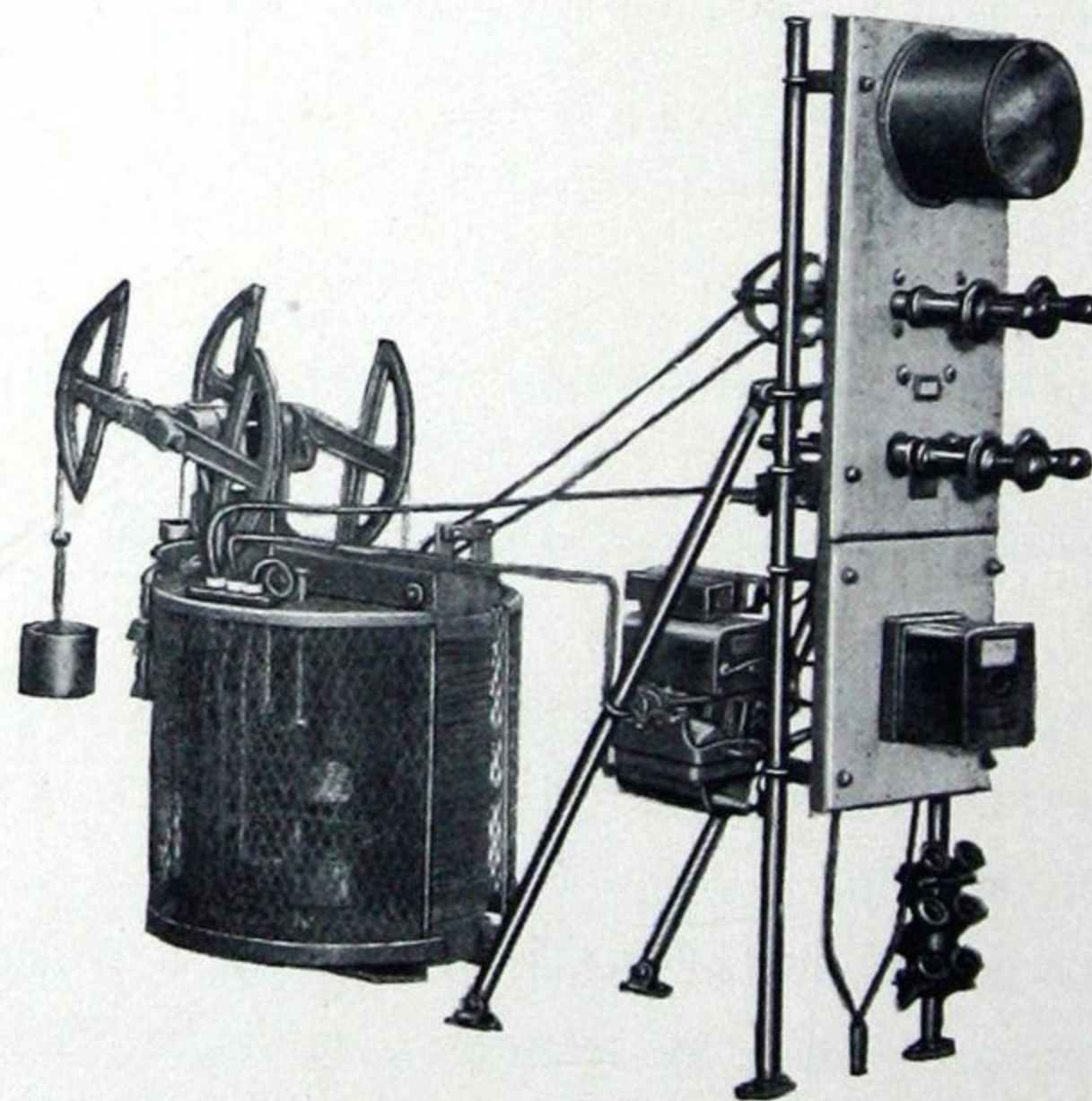
Plug Switch Panel for controlling one transformer and two secondary circuits

FOR the control of Type RV transformers plug switch panels are ordinarily used. These are rated on the basis of transformer kilowatt output at unity power-factor. The panels are made to control either one or two circuits of lamps. Two-circuit panels up to and including 30 kilowatts are for transformers with single-circuit secondaries. For above 30 kilowatts the panels are arranged for transformers with multi-circuit secondaries. The panels are made of blue Vermont marble mounted on pipe framework 64 inches high. They are intended for installation near the transformers which they control and are not suitable for assembly in a switchboard. The primary switches consist of combined plug switches and expulsion fuses which are of such a capacity as to rupture the circuit only under the emergency condition equivalent to a short circuit on the transformer. Open circuiting secondary plug switches are provided on all panels for the purpose of disconnecting the line from the secondary of the transformer when testing for ground or open circuit. For panels controlling two lamp circuits, short circuiting switches are provided to permit the operation of one circuit while the other is shut down.

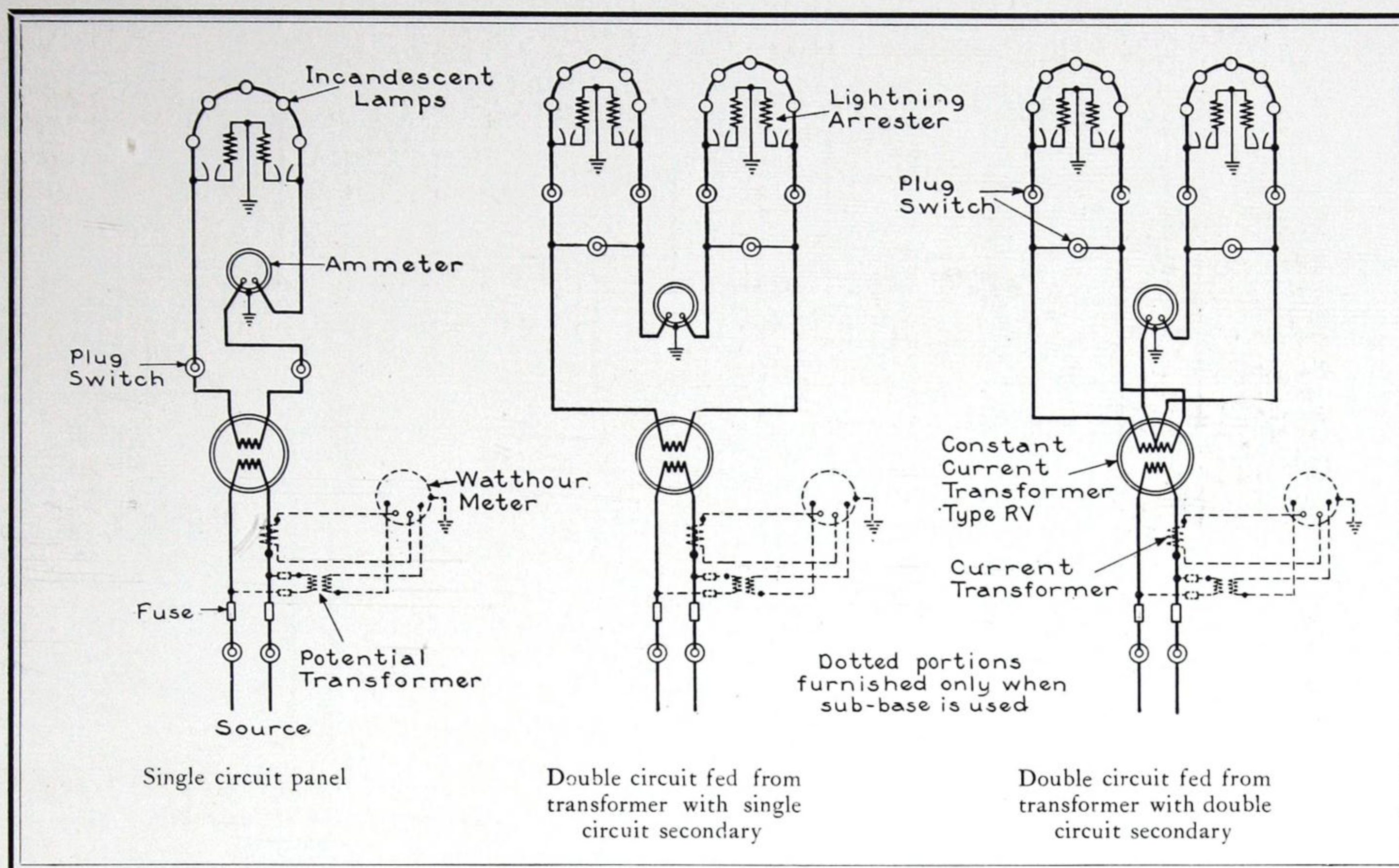
The ammeters, Type R-6, are connected directly in series with the secondary circuits, and on all panels on which the secondary potential exceeds 2300 volts, the ammeter is provided with an insulating cover.

If desired, a subbase to match may be had with the plug switch panel. On this are mounted a Type IS-4 single-phase watthour meter together with the necessary current and potential transformers and fuses. The watthour meters are for the purpose of recording the total input of energy to the constant current transformer. Central station managers will appreciate the advantages of this equipment as providing a means of accurately determining the cost of energy for the lighting system.

Panels for the control of Type RV transformers by means of oil circuit breakers are also available. These panels are made for a single transformer supplying one or two series circuits and may be used the same as the plug switch panel; it has additional features of safety and

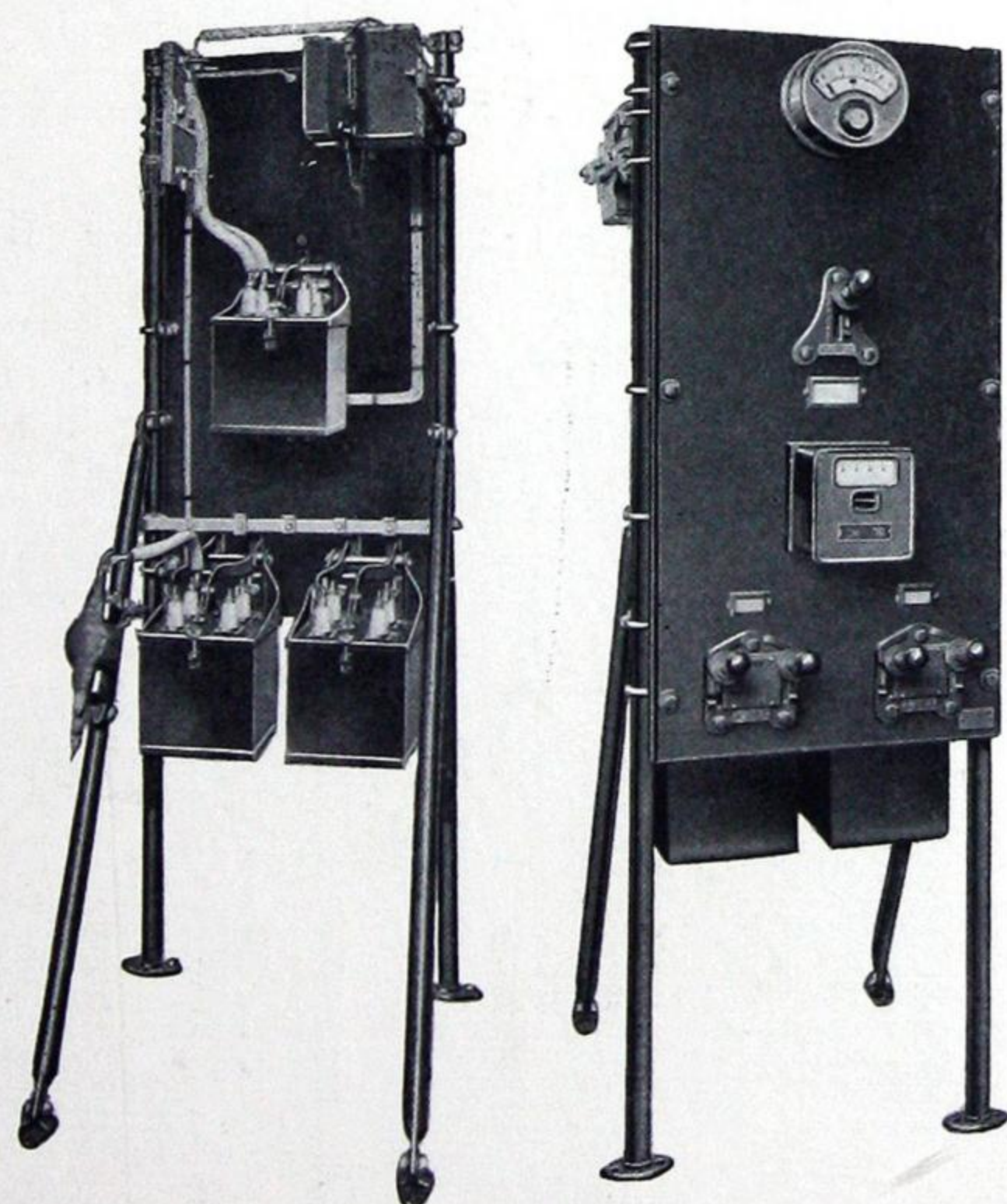


Type RV Transformer and Single Circuit Control Panel with subbase for watthour meter



Circuit diagrams for Type RV Transformer with plug switch control panels

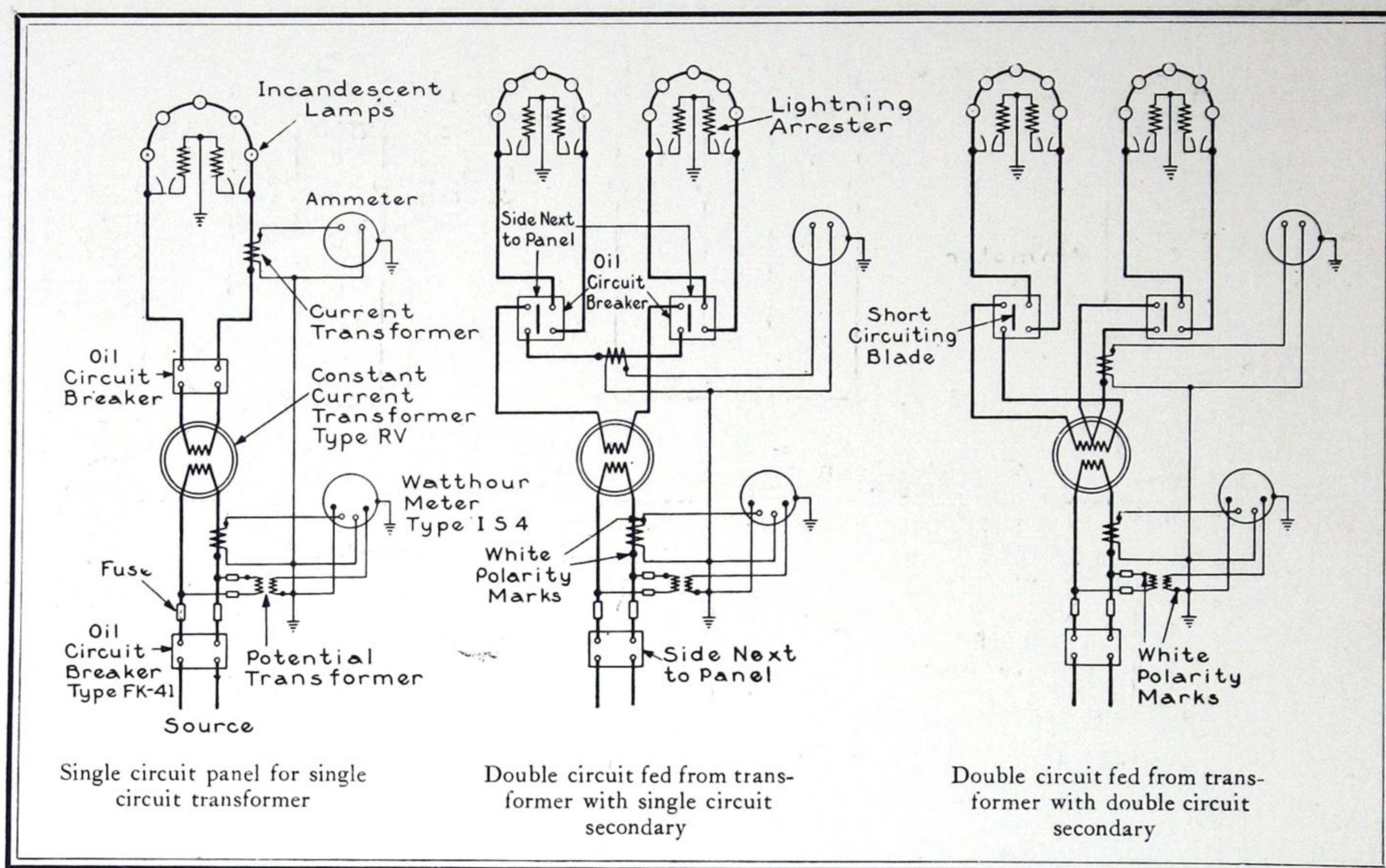
convenience, however. The oil circuit breaker panels are made of natural black slate mounted on a self-supporting pipe framework 76 inches high. They are designed for installation near the transformers which they are to control and are not suitable for assembly in a switchboard. The oil circuit breakers for both the primary and



Back and Front views of double circuit panel using two FK-41 oil circuit breakers for controlling a single circuit Type RV Transformer

secondary are Type FK-41 non-automatic manually operated. Short circuiting contacts are included in the secondary circuit breakers for the operation of two series circuits from a single transformer. Fuses are furnished for overload protection. The Type R-6 ammeter in the secondary circuit is insulated from the high voltage circuit by a current transformer. A Type IS-40 watt-hour meter with current transformer, potential transformer and fuses is regularly furnished with this panel. There are no high voltages on the front of this panel, no exposed current-carrying parts behind, and all circuits are opened and closed under oil which reduces burning of contacts and fire hazards from open arcs.

The maximum of safety is reached in the removable truck type panel mounting of

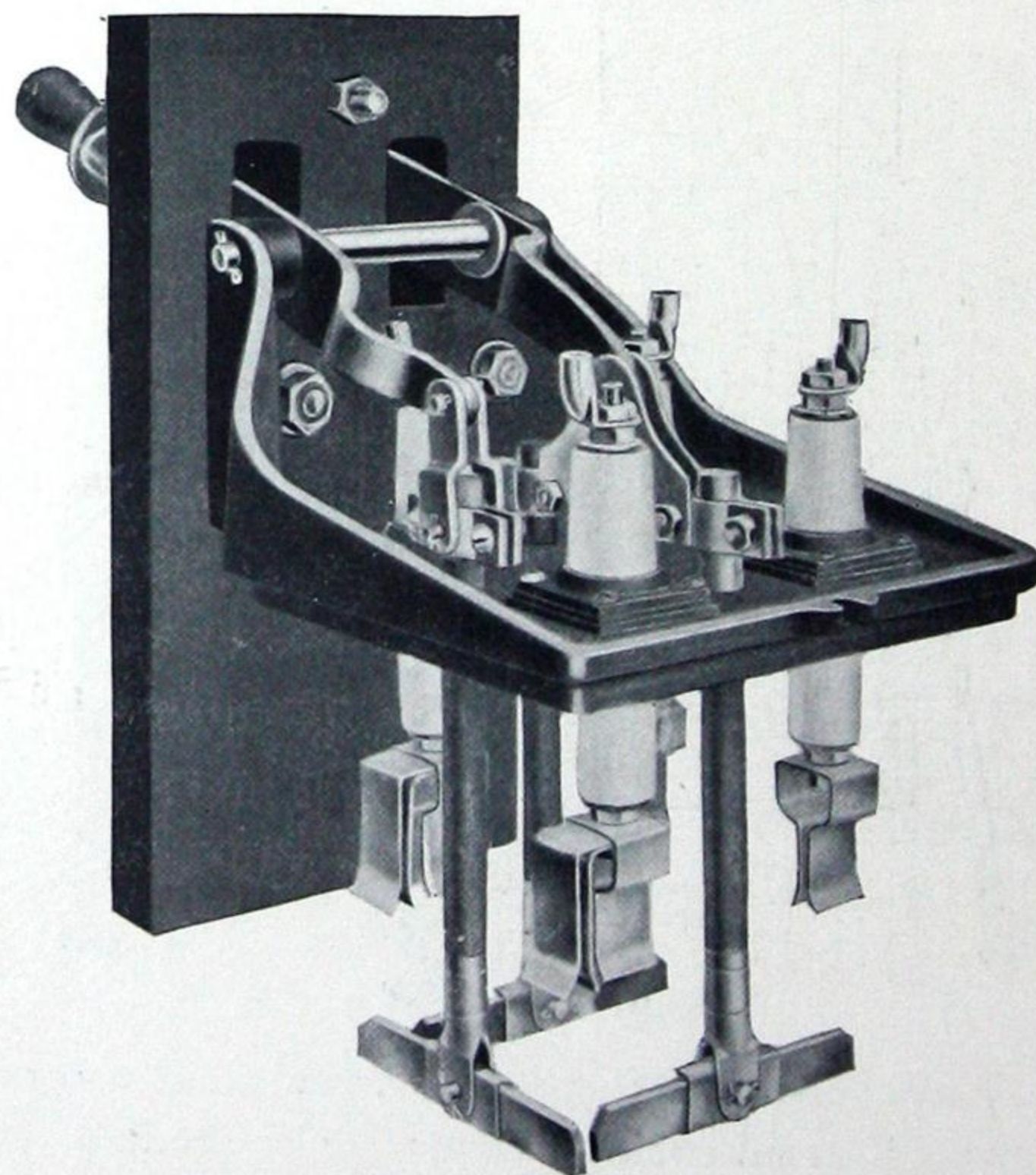


Circuit diagrams for Type RV Transformer with Type FK-41 oil circuit breaker control panels

the RV transformer and control equipment. In this arrangement the transformer is mounted on a truck on the front of which is a steel panel with a Type FK-41 Oil Circuit Breaker, indicating lamps and whatever meters and instruments may be desired. Access to the transfer is obtained by pulling the truck from its housing which automatically disconnects the transformer and equipment from all circuits. When in place the front of the panel is absolutely dead, and the truck is automatically locked into its housing when the circuit breaker is closed.

Not being automatic in action the Type RV Transformer cannot be controlled by contactors or time switches.

As many central stations suffer enormous losses each year resulting from lightning, horn type lightning arresters with series resistances are recommended for the protection of constant current circuits. Lighting circuits are usually confined to city limits, consequently the principal sources of trouble are not the high frequency disturbances but low frequency surges set up by sudden opening of the loaded circuits. These disturbances are especially severe when circuits are

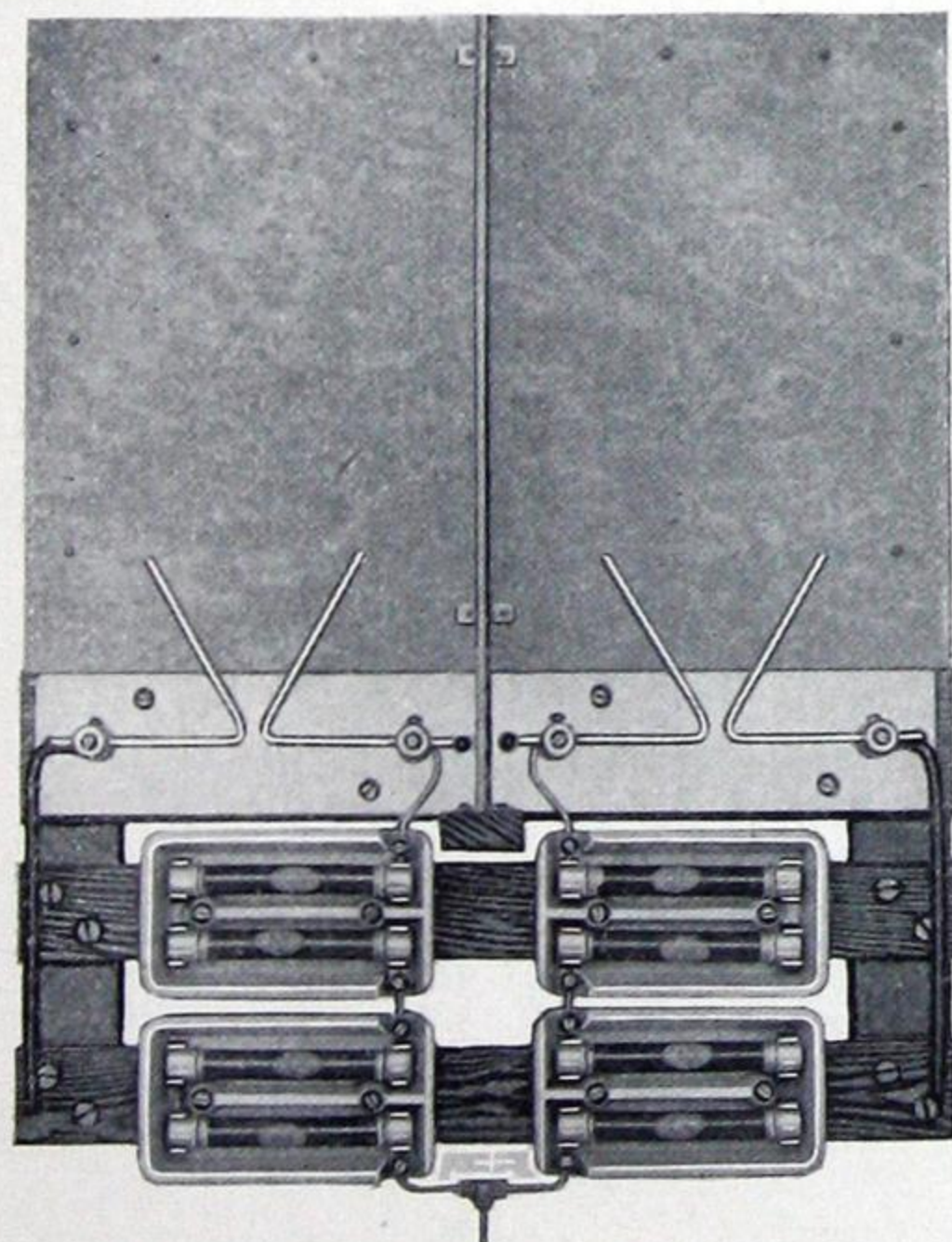


Type FK-41 oil circuit breaker with short circuiting switch. Oil tank removed to show contacts

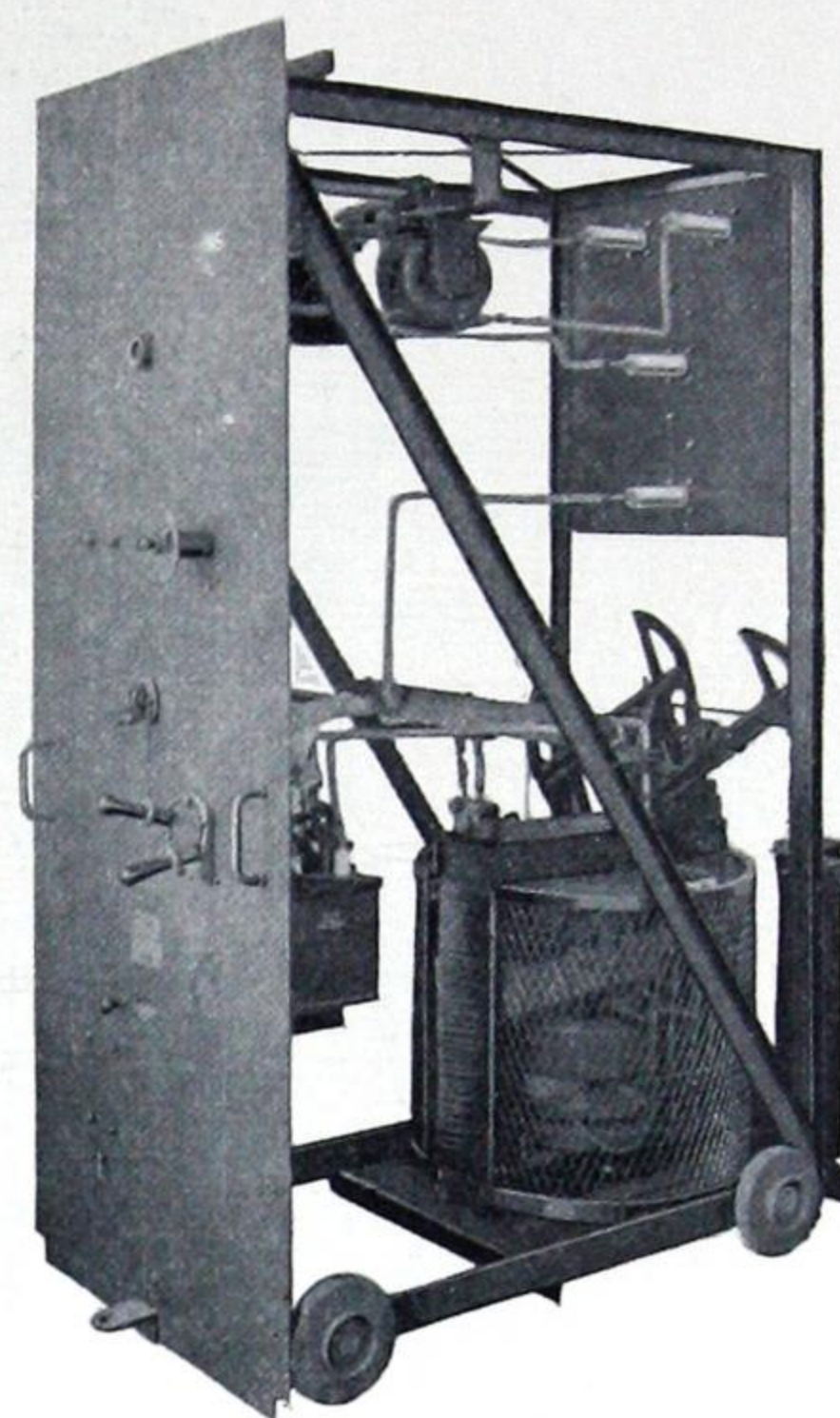
accidentally grounded due to contact of the wires where they pass through the tops of trees or become crossed with other circuits. The horn type arrester is most satisfactory for this service as the surge set up by the sudden opening of the circuit is dissipated by the arrester before the arc is interrupted. The arc usually lasts for several cycles as the operation of the arrester depends upon the lengthening of the arc, limited by the series resistance. The resistance aids the horns in extinguishing the arc, limits the size of the arc and prevents short circuits occurring during the period of discharge. It is recommended that these arresters be installed in the station on each outgoing line and that particular attention be given to connections, especially those to ground.

The rating of the lightning arrester depends upon the open circuit voltage of transformers. When single-circuit constant current transformers are operated with multi-circuit panels, lightning arresters should be installed on each circuit and each arrester should be rated at the total open circuit voltage of the transformer. The indoor horn gap lightning arresters are built in double-pole units; therefore only one unit is necessary on each circuit.

Other types of lightning arresters may be used, but they should be rated at a voltage equal to the total open circuit voltage of the transformer with which they are to be used.

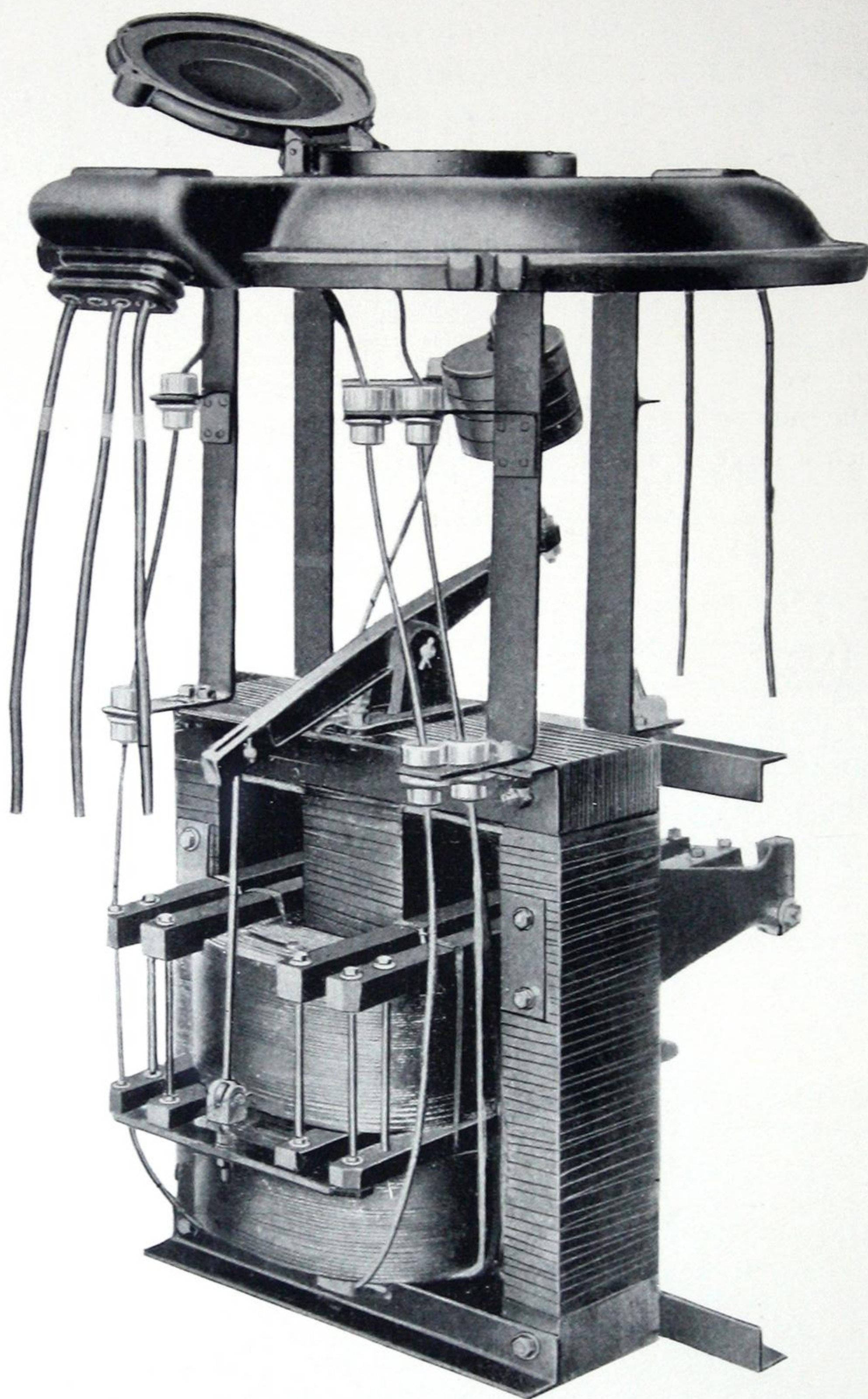


*Horn Gap Lightning Arrester
for indoor service*



*Safety removable truck type panel
mounting and control for
Type RV Transformers*

A constant potential transformer may be seriously injured by heating due to a short circuit or overload on the secondary. With a constant current transformer this cannot happen because the current, even under short circuit conditions, is maintained constant. "Overload" with reference to constant current transformers, therefore, does not mean what it does when used in connection with constant potential apparatus. If a series transformer is loaded with too many lamps, for instance, its regulation will fail, that is, it will not maintain the current constant, and the lamps will burn at reduced brilliancy. However, fuses for overload protection are desirable in case of internal injury to the transformer and are provided on control panels.

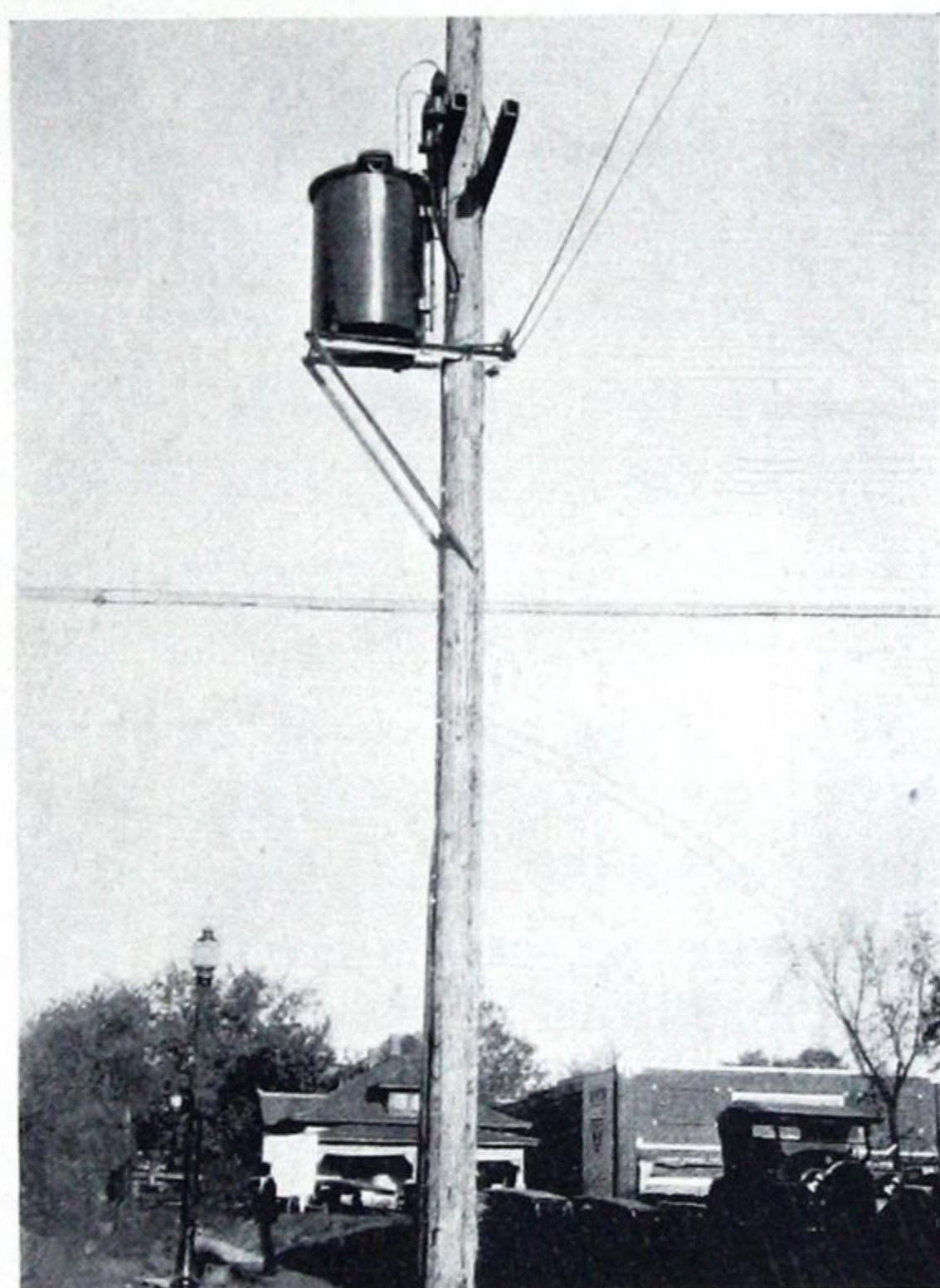


TYPE RO TRANSFORMER

An automatic outdoor constant current regulating transformer for feeding series street lighting circuits. This picture shows the transformer removed from its oil tank

AUTOMATIC OUTDOOR CONSTANT CURRENT TRANSFORMERS, TYPE RO

WHEN electricity stepped into the lead as a means of street lighting, and as street lighting itself assumed a position of increased importance, central stations were hard pressed to find shelter for constant current transformers and space on poles and in conduits for the wires of series circuits. The only way out of this predicament was the development of an outdoor constant current transformer, but on account of the moving parts and necessary adjustments it was long thought impossible to construct such a piece of apparatus which would be as serviceable and convenient to operate as the familiar constant potential distribution transformers.



A Type RO transformer installation

The General Electric Company was the first in the field with an automatic, outdoor, constant current regulating transformer, the Type RO, which is designed for pole mounting and intended to operate absolutely without attention in remote districts or where subdivided downtown lighting circuits are desired. This transformer excellently fills the demand for a constant current regulator for small installations, eliminating the need for substations or for additional central station room, and at the same time enabling the street lighting system conveniently to keep pace with the rapid growth of certain districts which would ordinarily require the expensive extension of high voltage series circuits or the erection of new substations. Furthermore, the Type RO transformer has met with immediate and enthusiastic approval from the smaller communities which, due to the expense of stations and attendants for series systems and the unsatisfactory operation of



Type RO Constant Current Transformer in oil tank for pole mounting

multiple circuits, had been, up to the advent of the Type RO transformer, unable to provide adequate street lighting service.

The Type RO transformer is built in sizes ranging from 1 to 30 kilowatts to operate at any commercial primary voltage and frequency or secondary current; but the standard transformer is for 60 cycles, 2300 volts on the primary and 6.6 amperes in the secondary. The 2300-volt transformer will operate satisfactorily up to 2400 volts and a tap is provided on the primary for operation as low as 2000 volts without reduction of output.

The pole type transformer, when once installed, needs no attention except for occasional inspections; it is positive and automatic in its operation. The entire unit is enclosed in a round, welded, steel tank with a cast-iron cover. It may be suspended from the cross arms of poles by means of suspension hooks which are furnished with it; however, sizes which

weigh over a thousand pounds should also be supported by platforms.

In designing this transformer so that it should be automatic and suitable for outdoor installation, care was taken to sacrifice nothing in its regulation which is as good as that of the best station type transformers, i.e., the current is maintained within *one per cent* of normal from full load to dead short circuit. At the same time the efficiency is equal to that of station type transformers and the power-factor is 25 per cent higher than for any previous design of pole type, automatic, regulating transformer.

In operation, the Type RO is similar to the Type RV, but in construction it differs considerably. Instead of being entirely supported by the balancing mechanism, the moving coil is pivoted at one side on ball bearings and counter-balanced on the other by a weight acting through a lever and connecting link. All moving parts have been made as light as possible for quick response to fluctuations in load, yet they are rigid and strong. The core and coils of the transformer are suspended from the tank cover in which there is a hand hole for inspection or adjustment. The leads are all brought out through porcelain bushings in the cover.

High internal reactance serves to protect the lamps at starting and acts instantaneously to check surges on the line which would otherwise tend to shorten the life of the lamps.



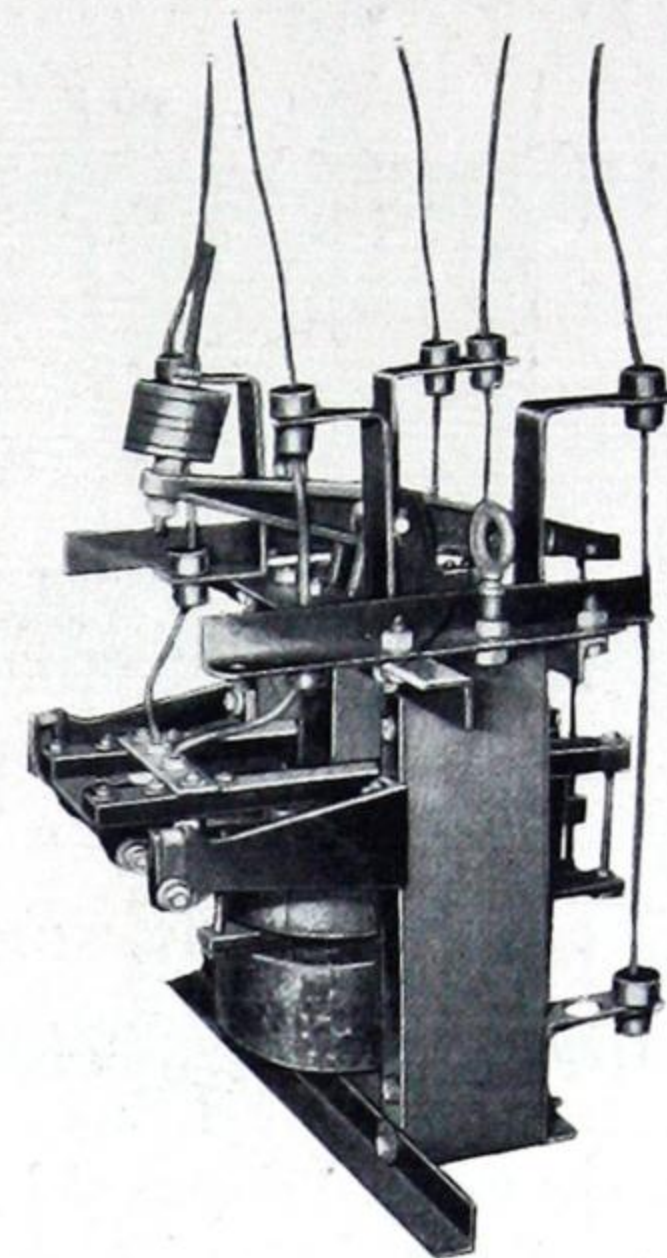
A small Type RO Transformer in subway oil tank

The Type RO transformer is oil cooled. Vertical ducts in the windings allow circulation of the oil in which everything but the balance weight is submerged. A welded steel tank and a cover fitted with gaskets keeps the oil in and moisture out. The temperature rise will not exceed 55 degrees centigrade by resistance based on a surrounding air temperature of 25 degrees centigrade.

Adjustment and test for rated current and regulation are made at the factory and these adjustments should not be changed. Vertical mounting is desirable, but careful levelling is unnecessary because the operation and regulation of this transformer is practically unaffected by slight deviations from the vertical.

In the cores of all General Electric street lighting transformers non-ageing silicon steel of high permeability is used which insures low core loss and high efficiency. The tanks of the Type RO transformers are made of copper bearing steel with welded seams. The copper bearing steel is very resistant to rust and adds considerably to the life of equipment exposed to the weather.

The installation and operation of the automatic outdoor constant current transformer requires no special tools or skill. Ordinary care in unpacking, connecting and filling with oil should insure good service.

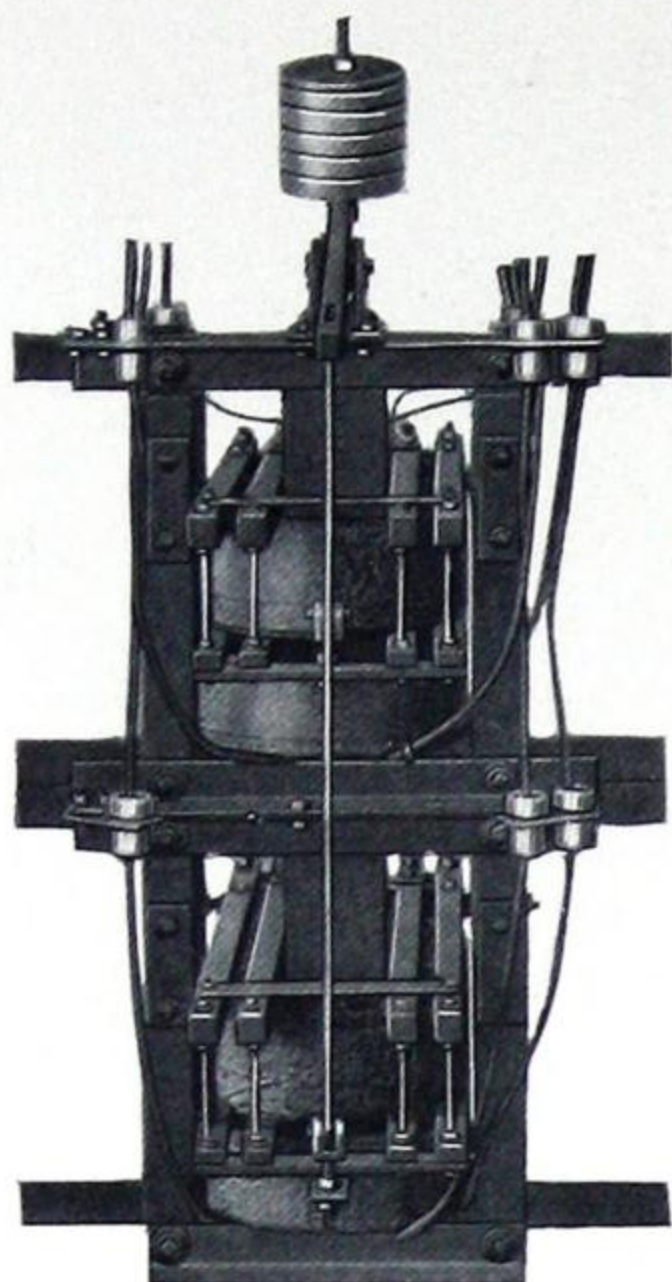


*Internal construction of
subway Type RO
Transformer*

GENERAL DATA ON THE TYPE RO TRANSFORMER

Transformer Output in Kilowatts at Unity Power- factor Load	Primary Input Kv-a.	SECONDARY VOLTAGE		EFFICIENCIES				PRIMARY POWER-FACTORS				Net Weight Including Oil Pounds
		Full Load	Open Circuit	100 Per Cent Load	75 Per Cent Load	50 Per Cent Load	25 Per Cent Load	100 Per Cent Load	75 Per Cent Load	50 Per Cent Load	25 Per Cent Load	
1.0	1.46	152	221	91.5	89.5	85.0	73.0	75	55	38	21	425
2.0	2.87	303	435	93.0	91.0	87.0	77.0	75	55	38	21	475
3.0	4.28	455	650	93.5	91.5	88.0	78.5	75	55	38	21	500
5.0	7.09	758	1075	94.0	92.0	89.0	80.0	75	55	38	21	600
7.5	10.58	1136	1600	94.5	92.5	90.0	82.0	75	55	38	21	750
10.0	13.90	1515	2100	95.5	94.0	91.5	83.5	75	55	38	21	775
15.0	20.95	2270	3180	95.5	94.5	91.5	83.5	75	55	38	21	1060
20.0	27.95	3030	4250	95.5	94.5	91.5	83.5	75	55	38	21	1100
25.0	34.70	3790	5260	96.0	95.0	92.0	84.0	75	55	38	21	1850
30.0	41.70	4550	6325	96.0	95.0	92.0	84.0	75	55	38	21	2000

The data contained in this table are for the standard 2300-volt, 60-cycle, 6.6-ampere transformer. This transformer can be used on circuits with potentials up to 2400 volts and an extra tap is provided in the primary to allow for operation circuits with potentials as low as 2200 volts.



Tandem arrangement of large size Type RO Transformer units for subway mounting

Subway type transformers must meet two conditions which pole type transformers do not: first, they must not only be weatherproof, but they must also be absolutely water-tight inasmuch as they may be subjected to complete submersion at times; second, they must be of such a size that they may be installed through manholes. These considerations affect the design of the tank principally; it must be water-tight and must be of such dimensions as to enter ordinary subway manholes which are generally 32 inches or more in diameter.

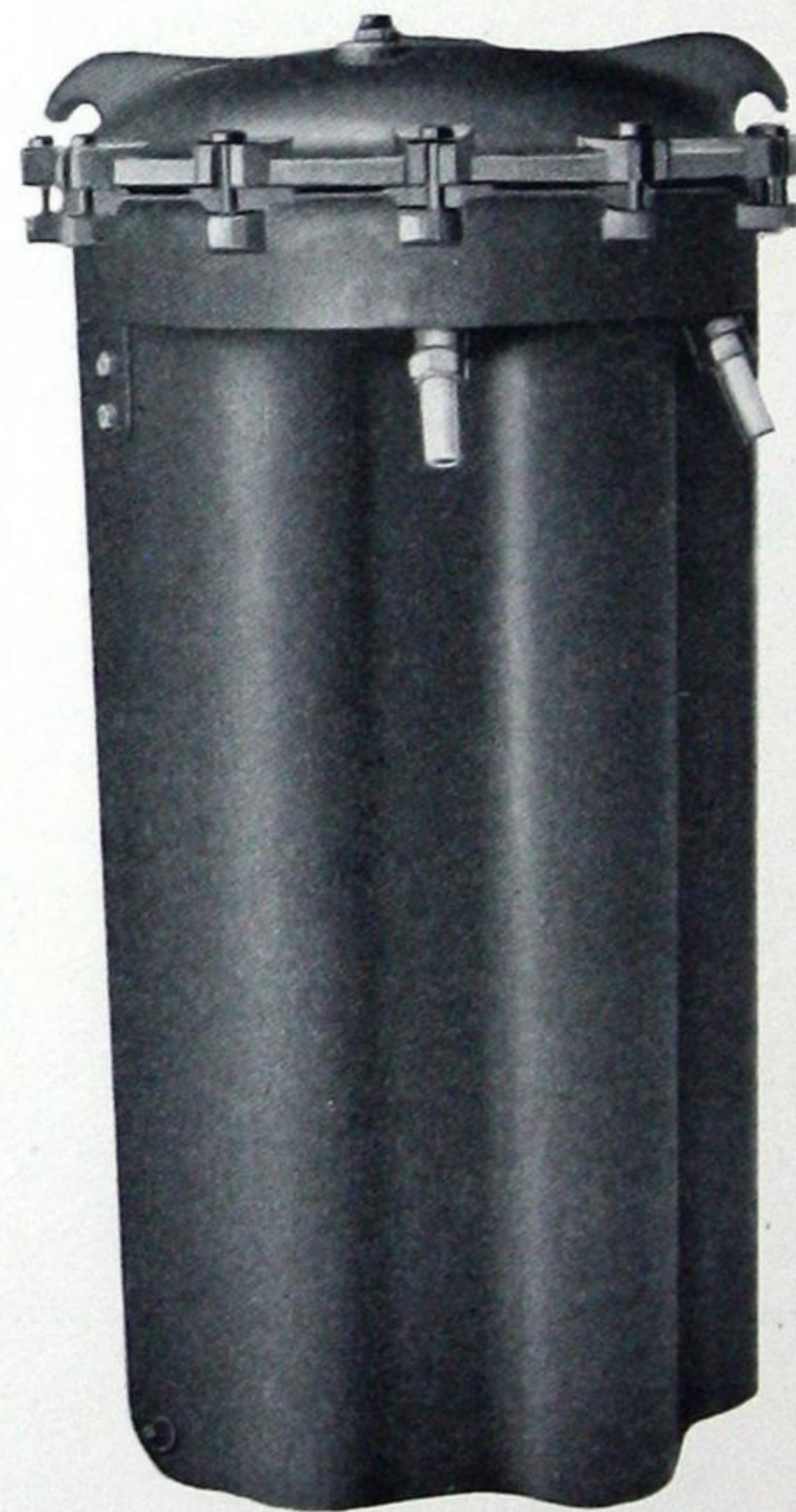
The Type RO transformer has been adapted to subway installation by making slight changes in the construction, and mounting it in a cast-iron tank, the cover of which bolts down on a water-tight gasket. Lugs are provided on the cover for lowering the transformer into the manhole. Wiping sleeves are provided for both primary and secondary leads.

In the larger sizes, the physical proportions of the transformer units were such that it was found impossible to put them in tanks small enough to enter a 32-inch manhole. Consequently a unique tandem arrangement was devised in which two transformer units were mounted one above the other and balanced by a common counterweight. These could be mounted in a slender tank which easily enters a manhole. In this arrangement there is not the slightest sacrifice in regulation.

The primaries of the two units may be operated in either series or parallel depending on voltage conditions; and, if desired, may be arranged for use in a Scott connection on a three-phase circuit. The secondaries can be connected in series to operate as a single circuit or may be operated as multi-circuit secondaries.

For overload protection, subway type fusible cutouts should be used.

Overload protection on any constant current regulating transformer is necessary only to disconnect the transformer in case of accident, since overheating due to abnormally high secondary currents is not likely to occur in connection with constant current devices. However, if the moving coil should become lodged, the primary winding damaged, or the balancing weights disconnected, serious injury might result if the transformer were not well protected. Hence the use of primary fuses is recommended.

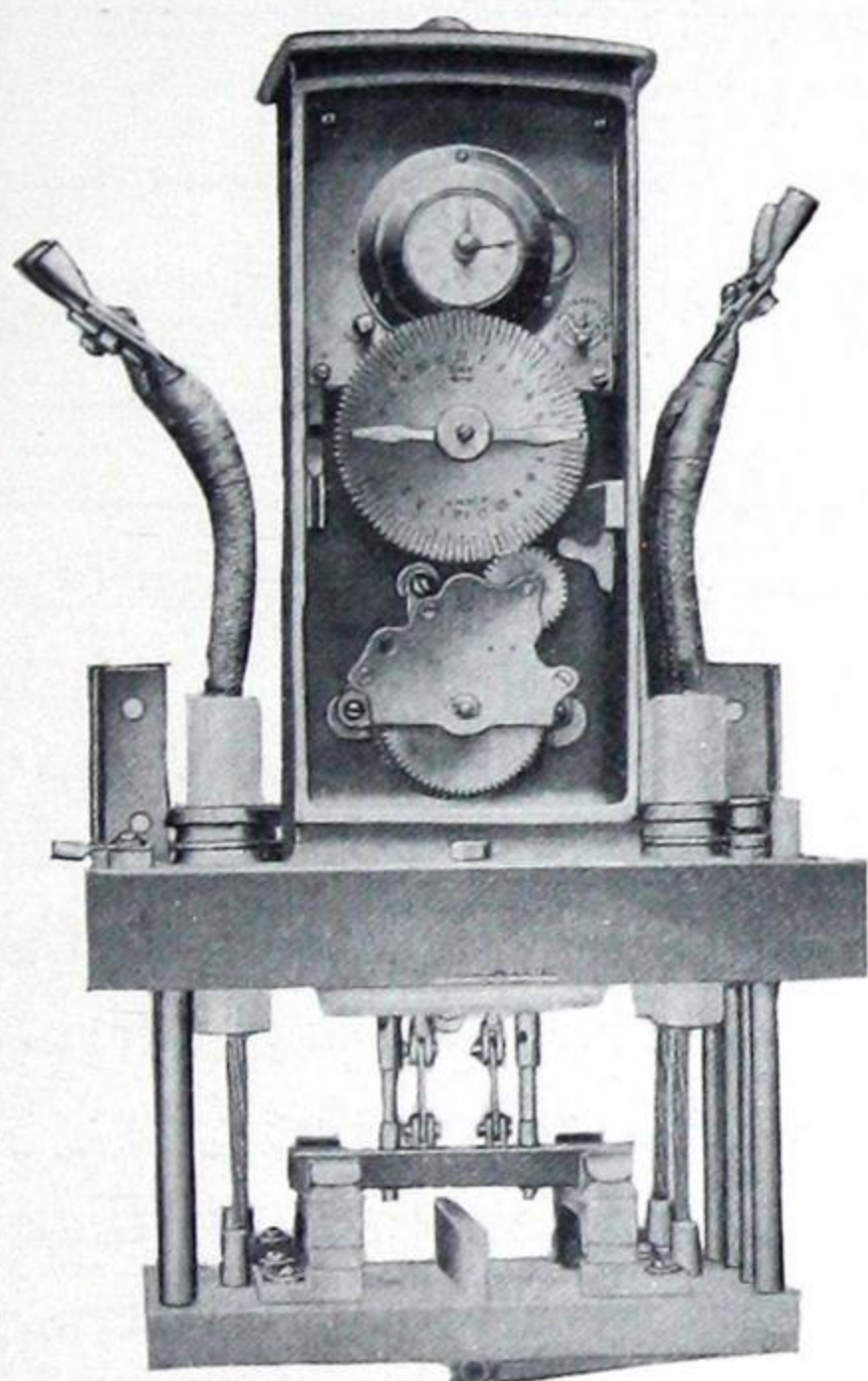


Large size Type RO Transformer in slender tank for subway installation

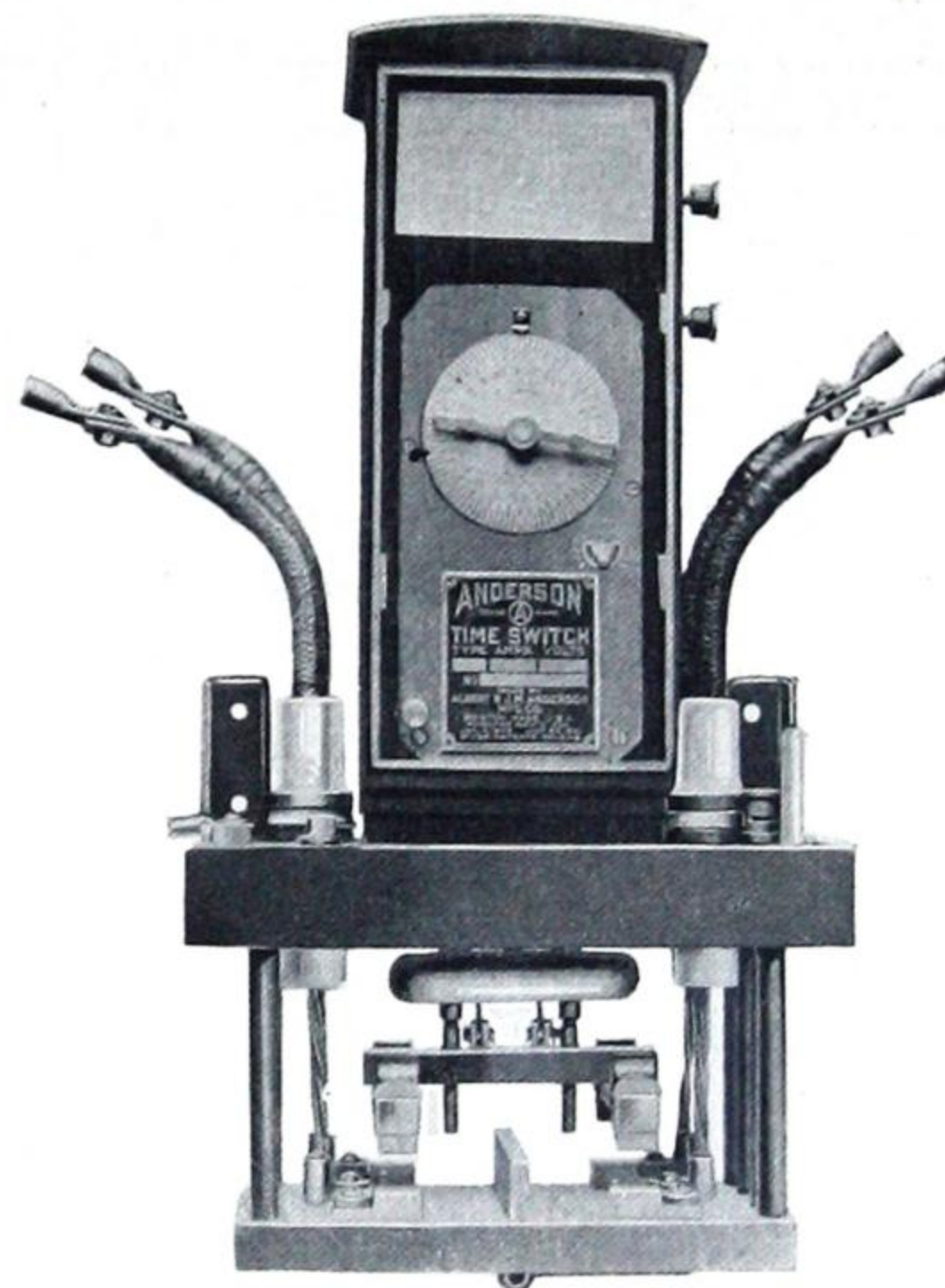
CONTROL AND PROTECTIVE DEVICES FOR THE TYPE RO TRANSFORMER

BEING entirely automatic, the Type RO transformer is easily controlled. The secondary circuit is left permanently connected to the load and closing the primary circuit is all that is required to put the transformer in operation.

The primary circuit may be closed by an FP-7 oil circuit breaker which is a manually-operated, non-automatic oil circuit breaker suitable for mounting either indoors or outdoors. The circuit is opened and closed under oil by knife blades operated by a handle on the outside of the weatherproof case. The whole is substantially constructed and



*Anderson Time Switch, Type L,
manually wound, with door
and oil tank removed*



*Anderson Time Switch, Type T,
electrically wound, with oil
tank and door removed*

thoroughly insulated. Double-pole single-throw units are ordinarily used, rated according to the voltage and current in the circuit.

In small towns or isolated locations, it is often expensive and unreliable to have an attendant turn the lights off and on by hand. In such cases automatic time switches are installed. The Anderson time switch is not merely an alarm clock which releases some kind of a lever, but it is an accurate and dependable time-piece which is mounted with and controls a well made oil circuit breaker. This time switch will open and close the electric circuit at the time set with absolute precision. It will close and open the circuit a number of times without resetting, thus requiring attention only once a week when winding is necessary. Its performance may be easily varied, as for instance, omitting the operation on Sundays or holidays and proceeding with the usual cycle on the following

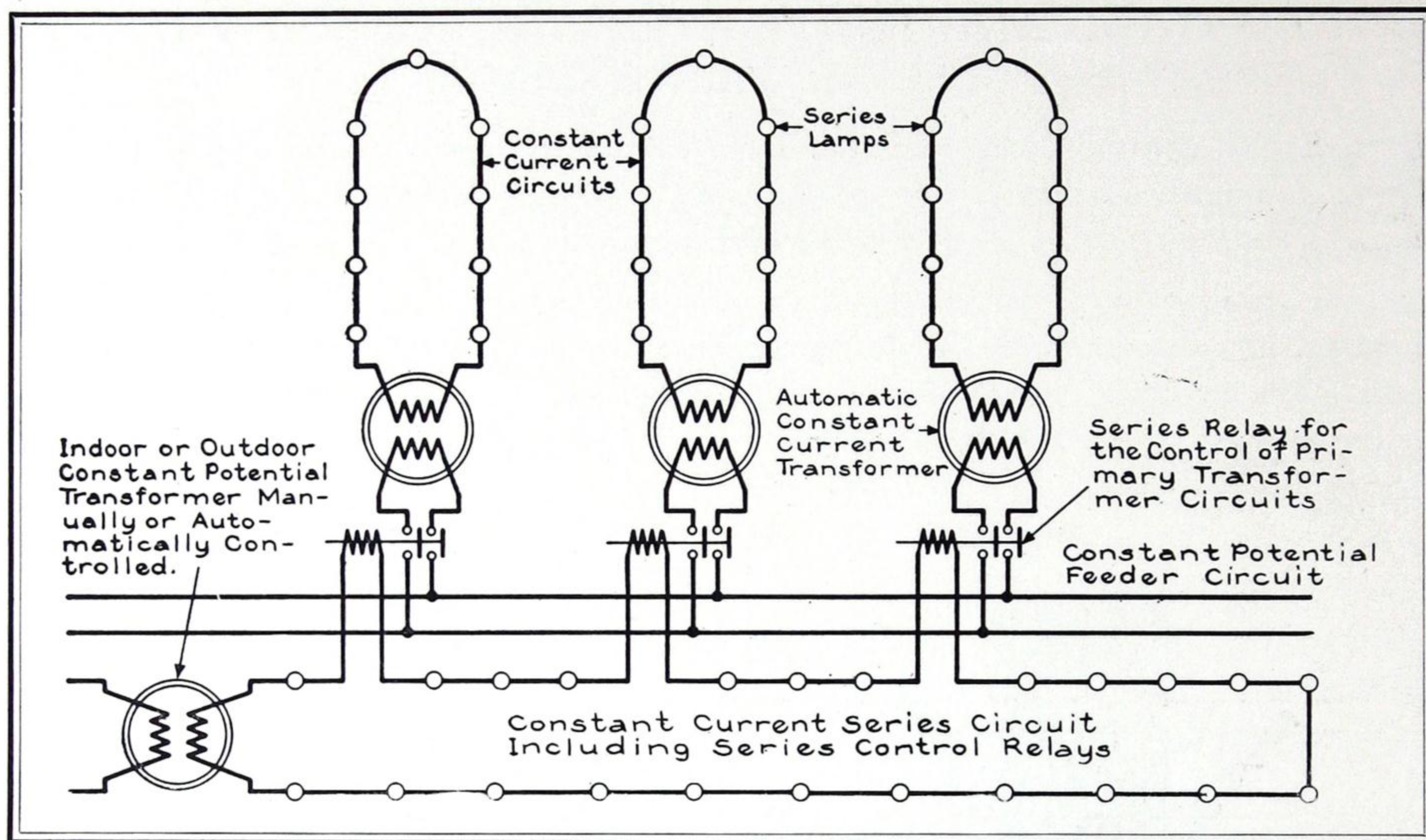
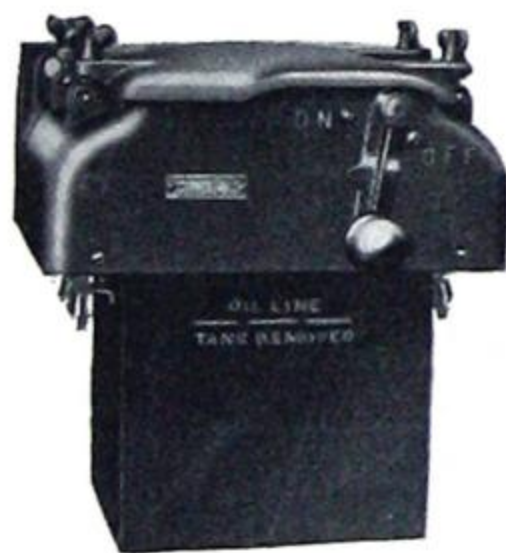


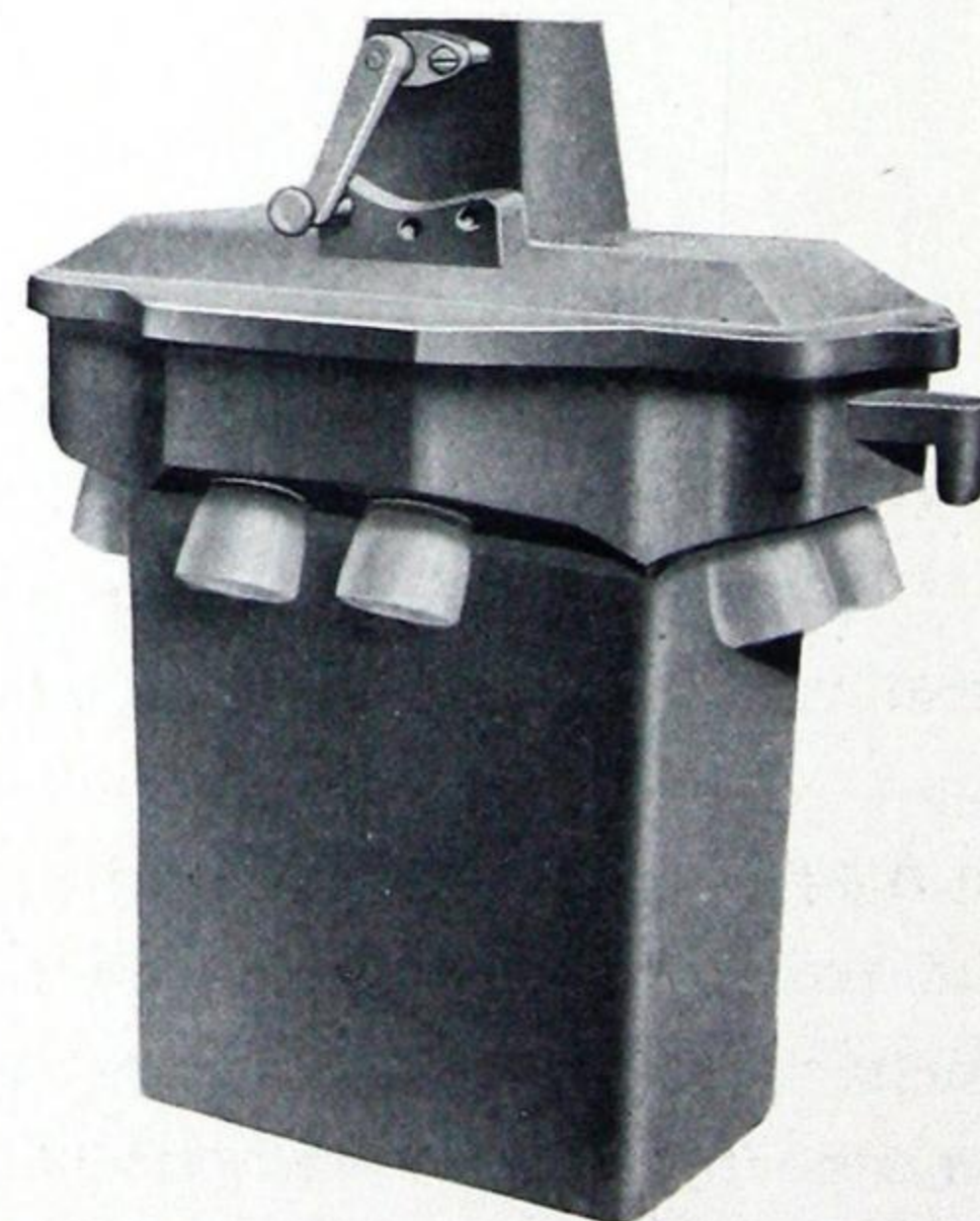
Diagram showing how several Type RO Transformers can be controlled by relays placed in a series lighting circuit which then acts also as a control circuit



Type FP-7 Oil Circuit Breaker

days. It is simple and substantial, has a water-tight case and is unaffected by sudden temperature changes. If desired, this switch can be equipped with an attachment for following the changes in the length of days in the different seasons of the year. An electrically wound model can also be had. The Anderson time switches are made double- or triple-pole, single-throw for 3300 or 6600 volts and 25 amperes current capacity.

Often series circuits are so installed that the entire street lighting system may be controlled by a single operator from a central point. In this case Type RO transformers are ideal for outlying districts, where they must give dependable service without attention. In some cases the transformers are all supplied from a special system of street lighting feeders. When these feeders are energized the lights come on; when the lights are off the feeders are dead. In other cases where it is desired to supply power for constant current transformers locally from the constant potential distribution system without installing special feeders, some form of relays or contactors are introduced to connect the primary of the transformer to the feeder.



Type CR2810-1304-A Combination Oil Contactor and Series Relay

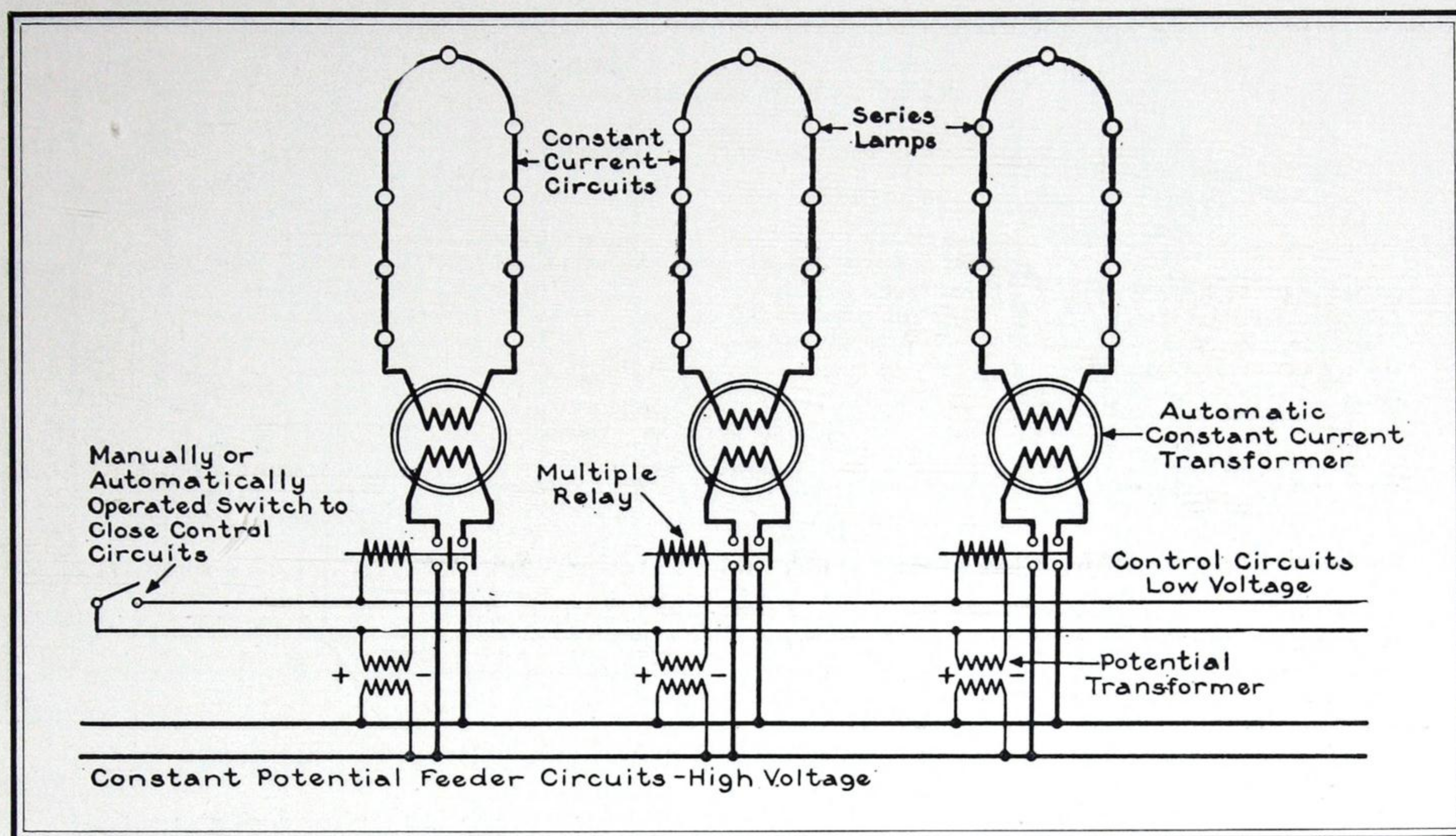
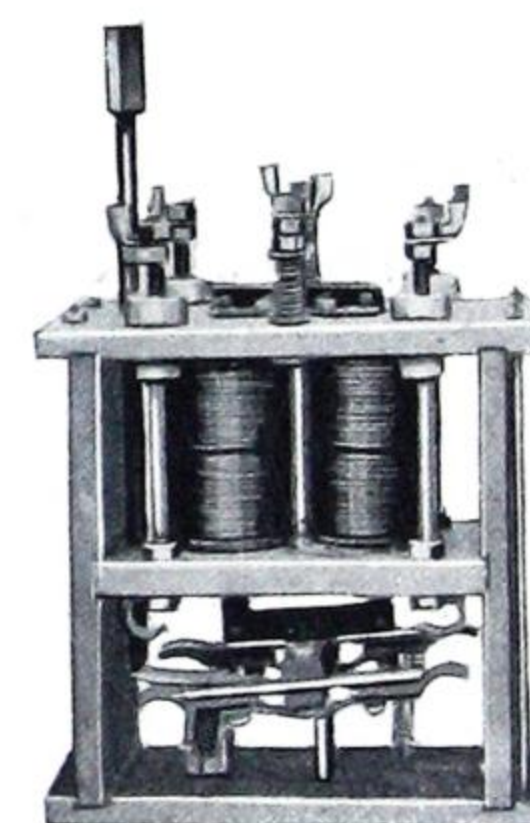


Diagram of pilot wire control Type RO Transformer. By closing a low voltage pilot circuit, contactors are operated which connect the transformers to the feeder circuit

Various methods of operating such contactors and relays are used. One method is to use a series lighting circuit also as a control circuit, inserting in it one or more relays to connect local constant current transformers to feeders. When the main circuit is turned on either manually or automatically all the series circuits controlled by it will be turned on. Another method is to "cascade" the circuits, that is, arrange them so that each one in turn controls the one beyond. When the first circuit is turned on, it will, through a contactor, turn on the second and the second the third and so on. A third method is to use a low voltage pilot circuit running from transformer to transformer giving low voltage multiple control of the series lighting system.

A combination series relay and oil contactor, Type CR2810-1304-A, is especially designed to control a Type RO transformer from a series lighting circuit. It consists of a 2300-volt multiple oil switch assembled in the same weatherproof case with a series relay insulated for 10,000 volts. The relay will operate on any frequency and coils may be had for any standard series circuit current. There is a 90-volt drop across the coil when used in 6.6-ampere, 60-cycle circuits, and the power consumption is 122 watts. The multiple oil switch will make, break and carry continuously 75 amperes. The whole unit is easily suspended by iron straps from a pole cross arm. A special feature of this unit is the lever on the top of the case, which may be moved into three different positions. The first position allows the apparatus to function automatically, so that when the relay is energized the contactor is engaged. The second position short circuits the series relay and



Type CR2810-1304-A
Contactor removed
from its oil tank

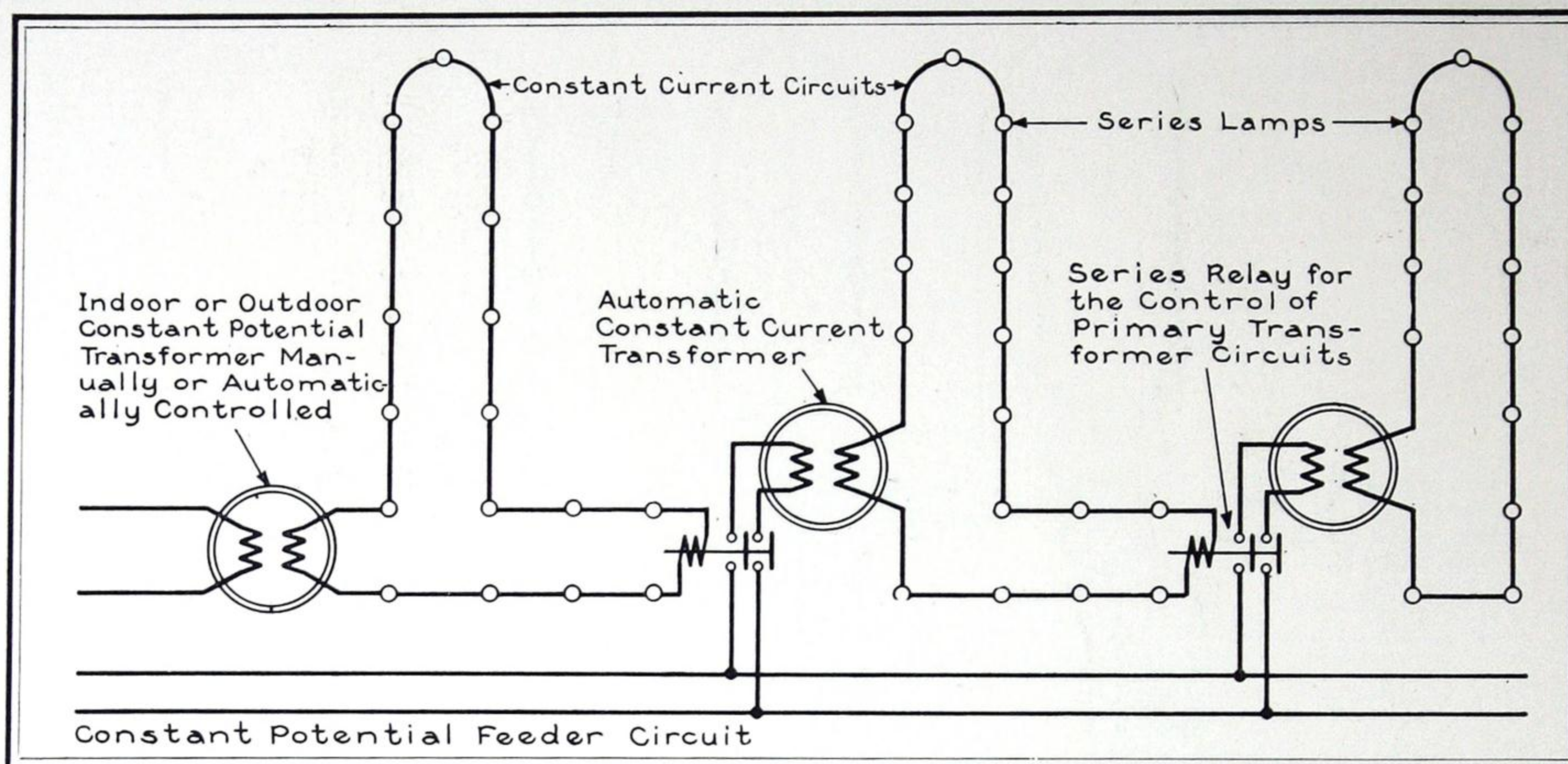
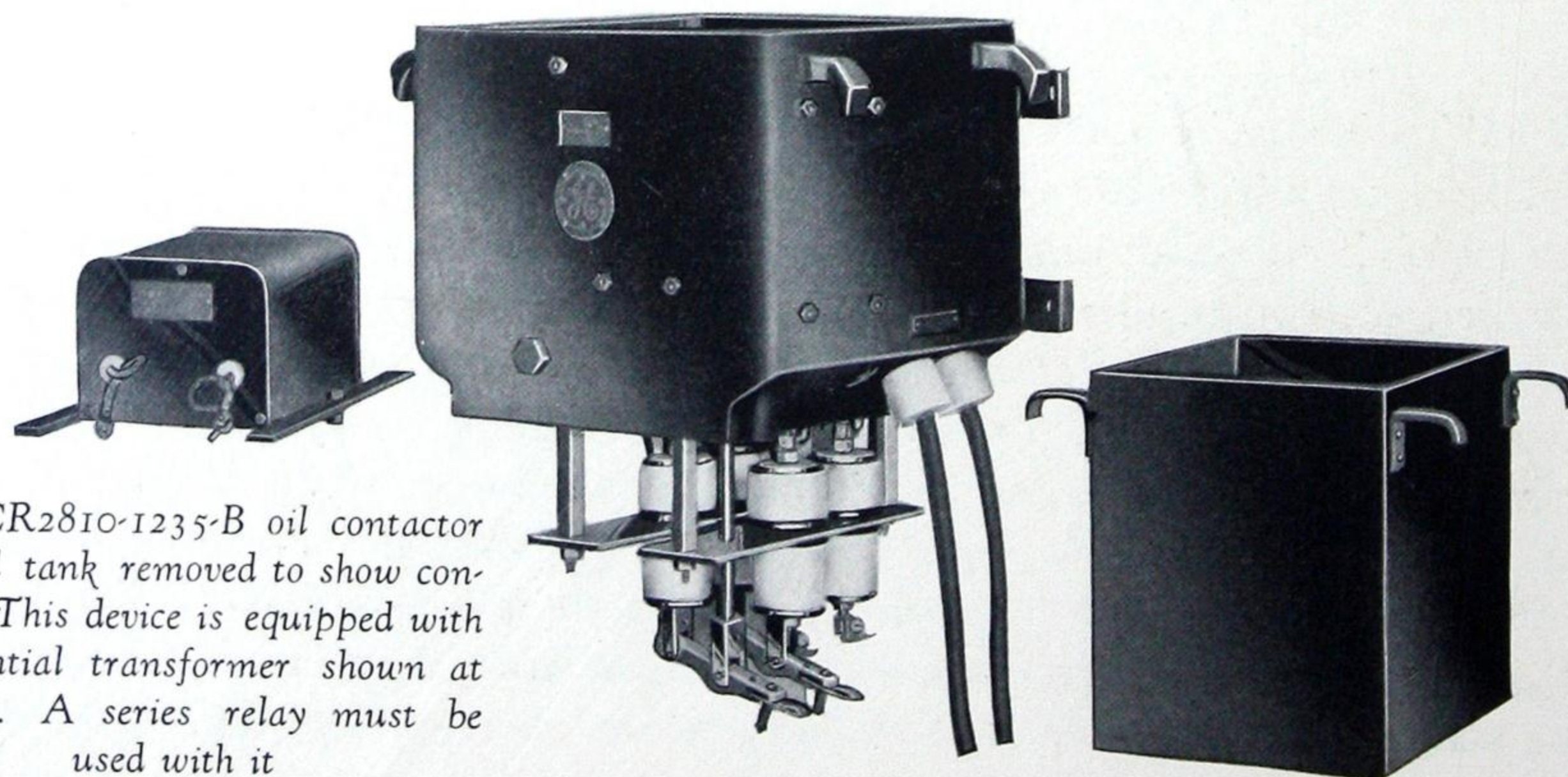


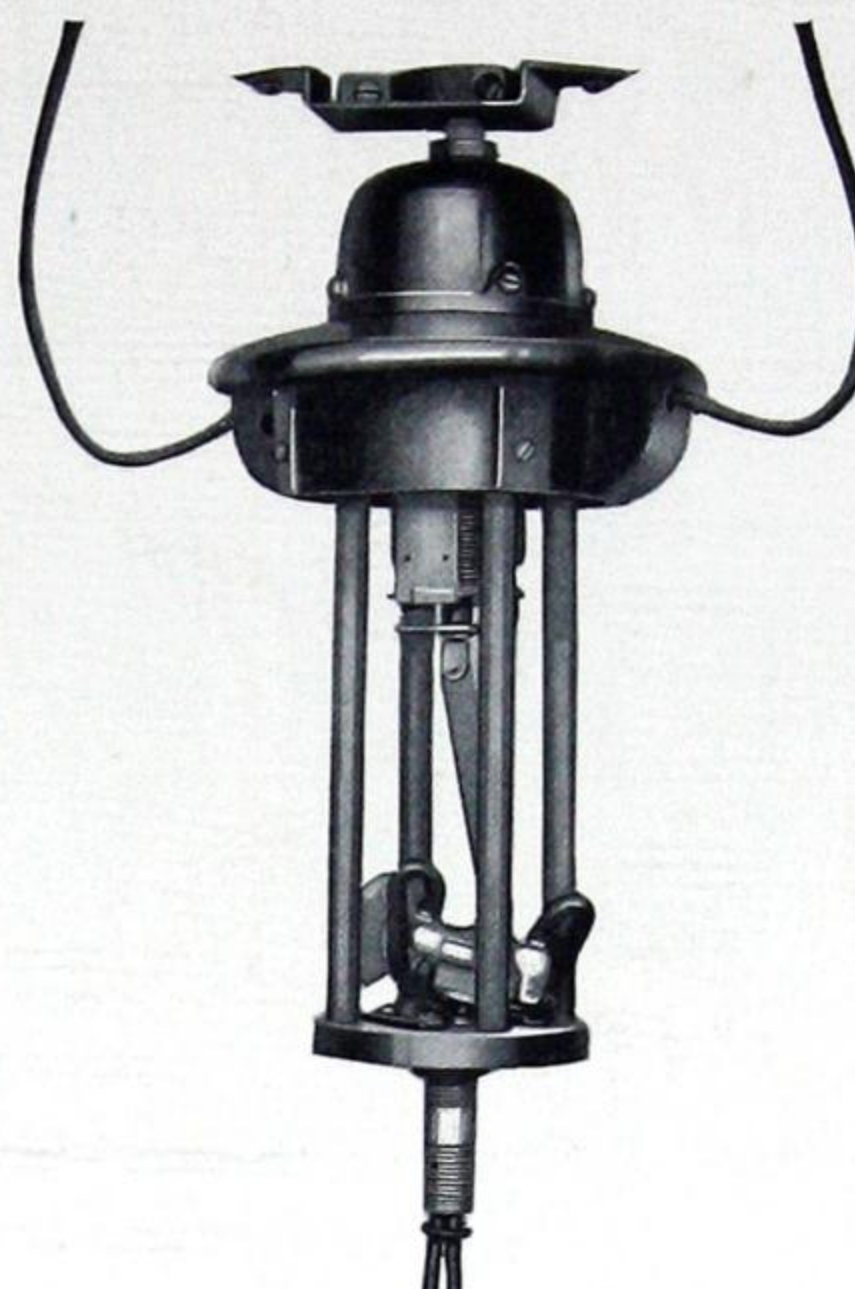
Diagram illustrating cascade control of series lighting circuits. Each circuit contains a relay which controls the one beyond

locks open the oil contactor so that no matter if the series circuit is turned on, the contactor will still be "off" and the transformer or line may be worked on with perfect safety. Position three engages the oil contactor without the series relay being energized which allows the transformer to be thrown into operation manually in case of failure of the control series circuit or for testing purposes.

When the feeder potential is above 2300 volts a separate relay and contactor are required. The contactor recommended is the Type CR2810-1235-B. This device is a double-pole single-throw oil switch which may be used on any frequency up to 60 cycles, potentials up to 4400 volts, and currents up to 75 amperes. The contacts are closed by a 110- or 220-volt solenoid, energy for which is supplied by a potential transformer connected across the feeder circuit. The contacts, solenoid and potential transformer are all included in a single weatherproof housing suitable for pole mounting. In conjunction with this contactor, a relay connected in the series control circuit or some other device



Type CR2810-1235-B oil contactor with oil tank removed to show contacts. This device is equipped with a potential transformer shown at the left. A series relay must be used with it

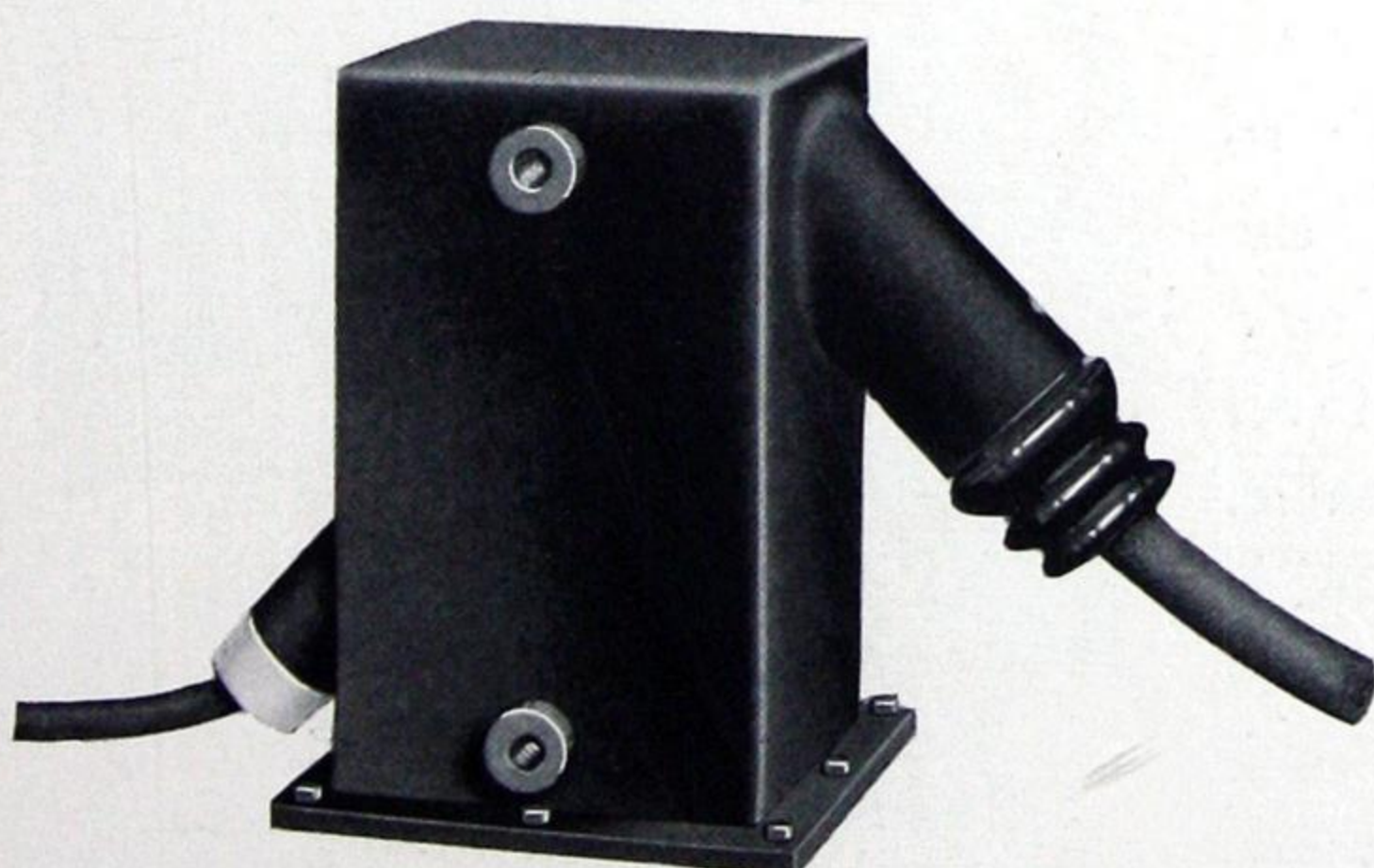


Series-multiple mercury switch with cover in place and with cover removed. This device is used for controlling a Type CR2810-1235-B oil contactor

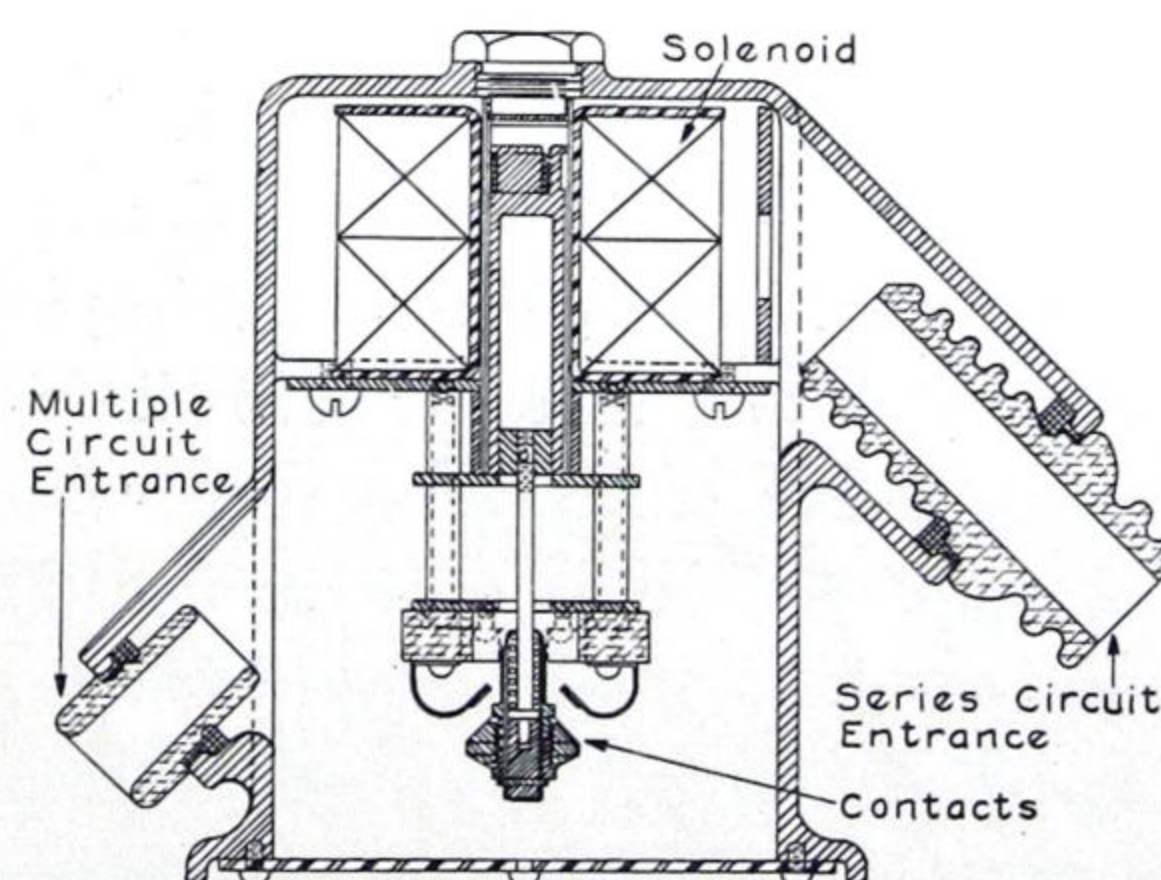
must be used to close the low voltage constant potential circuit through the potential transformer secondary and the operating solenoid of the contactor.

A series relay, Type PL-33, is supplied for this purpose. It consists of a compact operating coil insulated for ten thousand volts and suitable for connection in any commercial series lighting circuit, and a simple low voltage single-pole single-throw contact contained in a weatherproof housing. The contacts will carry five amperes on a 110-volt or 2.5 amperes on a 220-volt circuit, and the coil requires 30 volt-amperes to actuate the contact plunger on a 60-cycle circuit.

Another device for accomplishing the same purpose is a mercury switch for series-multiple operation. This consists of a coil mounted on a heavy porcelain insulator connected in the series control circuit and a standard 115-volt, 25-ampere mercury switch which is operated by it and closes the low potential circuit, actuating the high potential contactor and throwing the RO transformer on the line when the series circuit is energized. The mercury contactor has the advantage of entirely eliminating contact burning, since the circuit is broken by a liquid in a partial vacuum. The mercury series multiple switch may be mounted out of doors. It is interesting to note that the current carrying capacity



Type PL-33 relay for operating a Type CR2810-1235-B contactor



Sectional diagram of the Type PL-33 series relay



Fusible, primary cutout for overload protection of Type RO Transformers



Type T-5 time clock for operating a high voltage contactor, such as the Type CR2810-1235-B

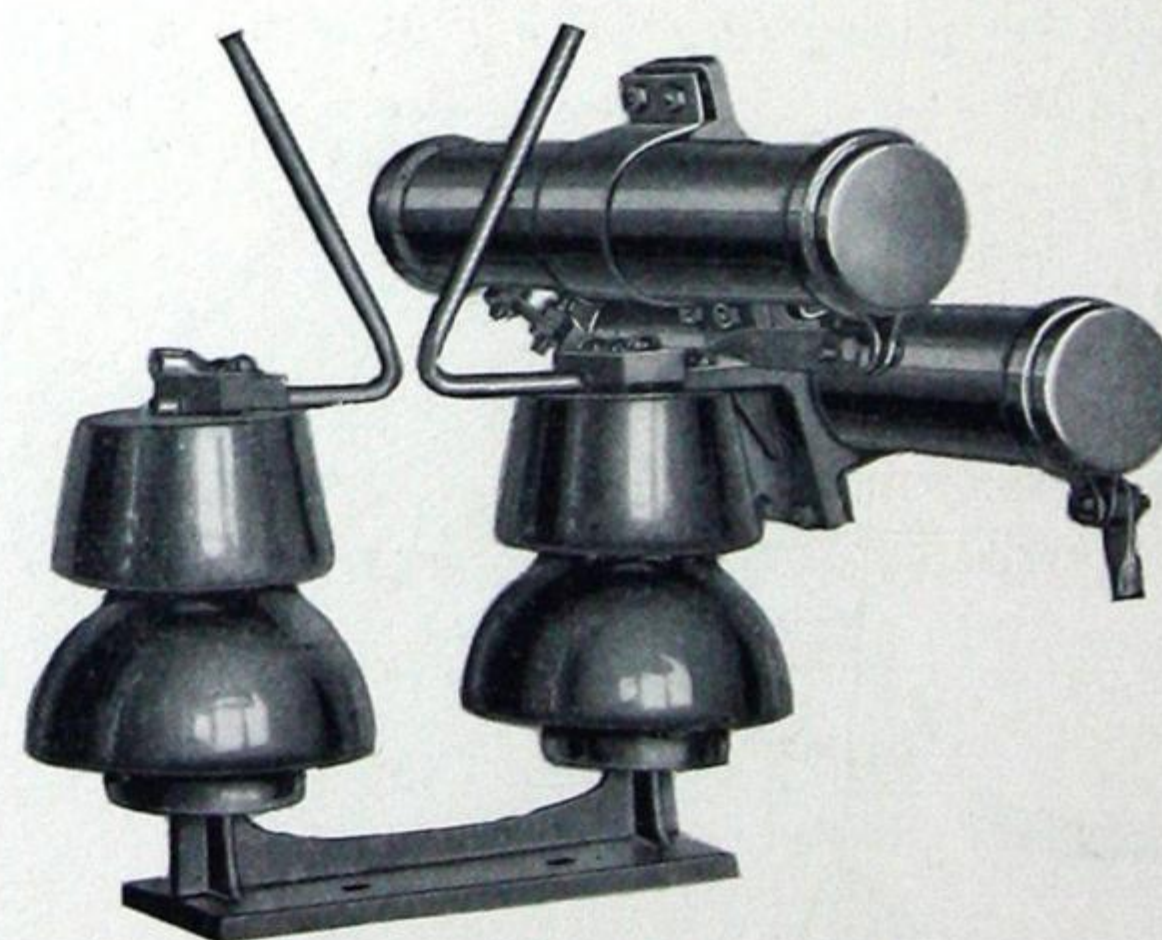
of this series-multiple mercury switch is sufficiently large so that it may be used to control directly a number of incandescent lamps on a 110-volt multiple circuit.

The Type CR2810-1235-B high voltage contactor may be operated in other ways than by series relays. Often the low potential circuits of several of these contactors are closed by means of a pilot circuit running to some convenient point where it may be closed by an ordinary knife or snap switch. In this manner a 110-volt line can safely and inexpensively serve to control one or more constant current transformers at a considerable distance.

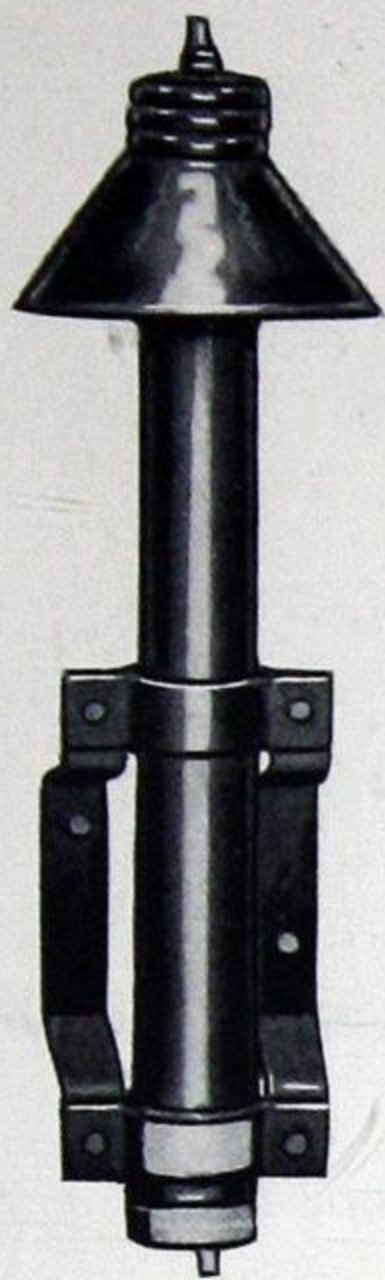
A time clock can also be used to close the low potential circuit of one or more contactors controlling Type RO transformers. This time clock does not need to be a heavy oil time switch such as the Anderson as described above, but it may be simply a little Type T-5 which will accomplish the same purpose on low voltage circuits at a much lower cost. This time switch must be wound weekly. Its contacts will carry 25 amperes and interrupt that current at 250 volts. An attachment can be had to prevent operation every seventh day.

The devices intended for the protection of Type RO transformers from lightning, line surges and overload are all quite similar to those used for distribution transformers of similar capacity.

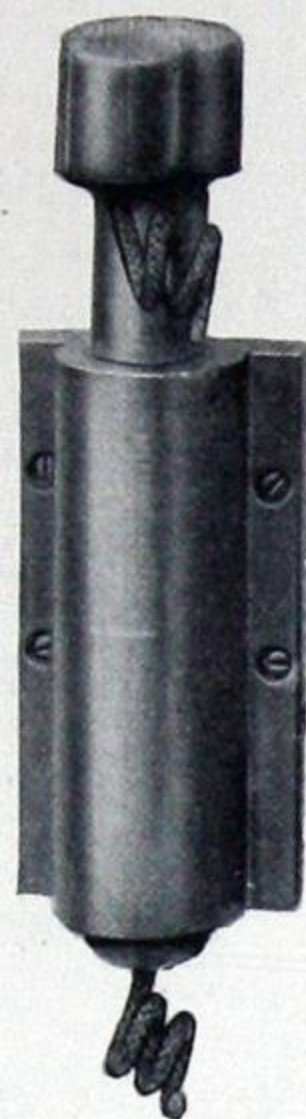
For overload protection, it is customary to use fusible cutouts on the primary side of the transformer. These are porcelain plugs carrying a fusible link and suitable contacts which connect corresponding contacts in a porcelain receptacle. The whole device is entirely weatherproof and is designed for pole mounting. Being made only in single-pole units, two are necessary for each transformer. The size of fuse links used depends upon the maximum current in the primary circuit of the transformer.



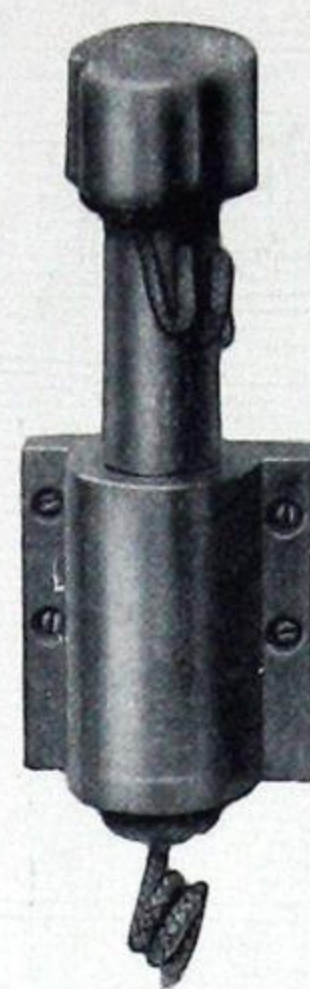
Outdoor horn gap Lightning Arrester for protecting the load side of a Type RO Transformer



For 30-Kw. Transformers



For 20 and 25-Kw. Transformers



For 7.5 to 15-Kw. Transformers

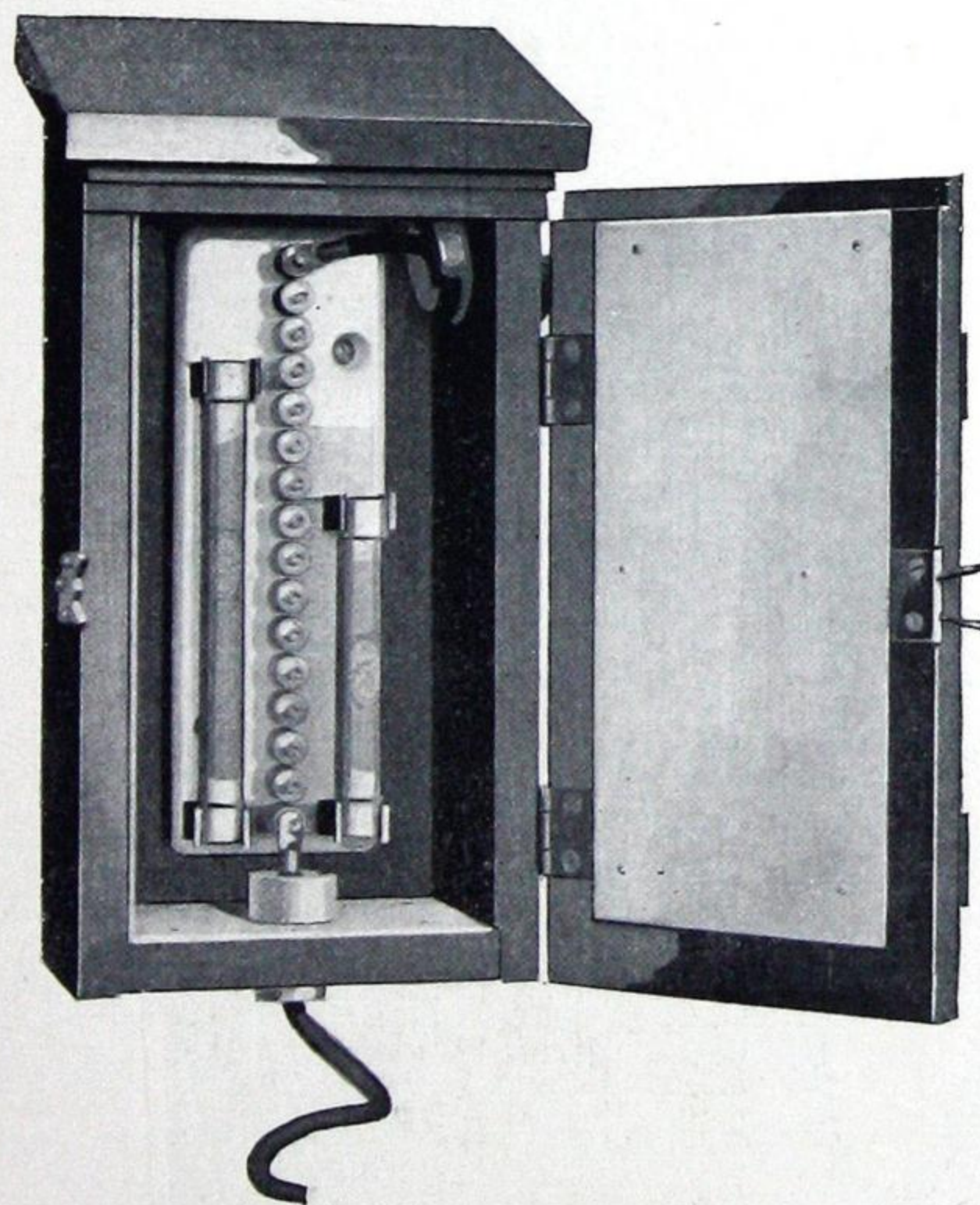


For 1 to 5-Kw. Transformers

Compression chamber, multigap, lightning arresters for Type RO transformers

For lightning protection on the load side of the transformer, outdoor horn gap or compression chamber arresters are recommended. Both of these may be mounted on poles and must be very carefully grounded to be effective. Being made only in single-pole units two are needed for the load side of the transformer, the voltage rating of each is governed by the maximum open circuit voltage of the series circuit.

For protection of the load side of the transformer, compression chamber multigap arresters are also suitable. Their voltage rating is determined by maximum secondary voltage. The essential feature of multigap lightning arresters is a series of zinc alloy cylinders spaced with small air gaps between and connected between the line and ground. These cylinders act as condensers which cause the arrester to discharge at a much lower voltage than in an arrester having a single gap equal to the sum of the small gaps. The effect of zinc vapor, which is produced in the gaps by heat of the discharge current, is to prevent reversal of the generator current which follows the lightning. These arresters are sealed in porcelain tubes with porcelain caps which make them weatherproof. Two per transformer should be used. These may also be used for the primary.



Graded shunt multigap lightning arrester for outdoor use

use, this arrester is mounted in a weatherproof wooden box equipped with cross arm hangers.

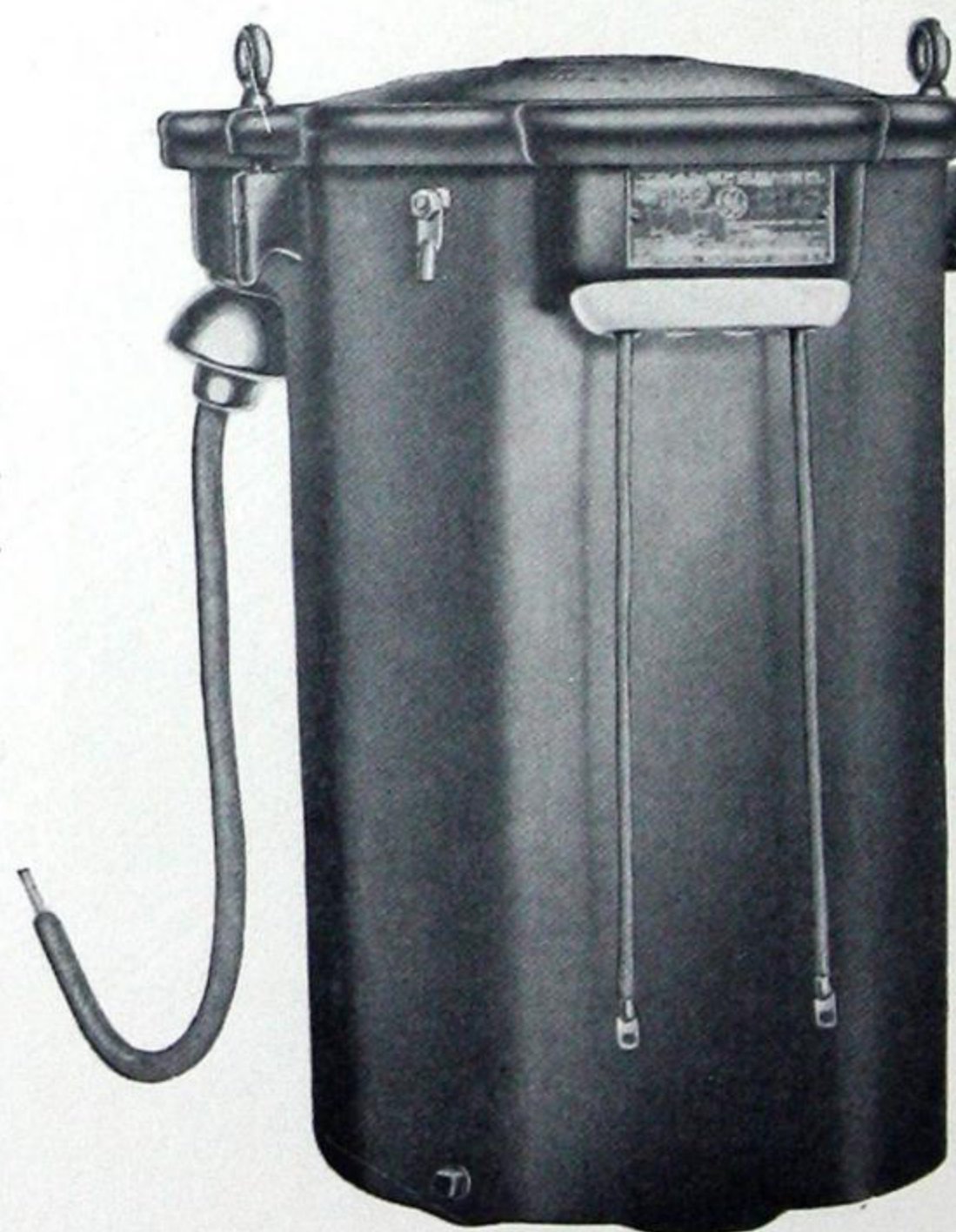


TYPE SL TRANSFORMER

This is a subway type series lighting transformer with a ratio of one-to-one for insulating groups of series street lighting units from the main high voltage series circuit. This picture is typical of the larger sizes

TYPE SL TRANSFORMER

This is an oil-filled pole-type series lighting transformer of one-to-one ratio for sizes of five, seven and one-half and ten kilowatts



SERIES LIGHTING TRANSFORMERS TYPE SL

THE Type SL transformer is used for supplying current to a small number of lamps connected in series and located where the high potential of the ordinary constant current series circuit would be objectionable. Certain classes of lighting, for reasons of safety, require lower potential than is found on long series lighting circuits, and yet, functioning similarly, it is desirable to control them simultaneously with the street lights. The Type SL transformer affords the ideal method for this control as the low voltage series circuit is turned on and off with the closing or opening of the main constant current transformer circuit. Some of the places where these transformers can be used to advantage are: on poles and elevated structures, where it is expedient to place a series circuit but



Type SL Transformer for pole mounting. Typical of smaller sizes. A separate protective device should be used with each transformer



Type SL Transformer for subway mounting. Typical of smaller sizes with integral protective device

where high potential would be objectionable, in isolated side streets and alleys where it is desired to install a few series incandescent lamps, on bridges, in underground circuits leading to ornamental poles, in installations for fire alarm boxes, police boxes or letter boxes, for lighting traffic signals and isles of safety, and for house or sign lighting near series circuits where constant potential is not available.

In operation, the primary winding is connected in the main series circuit so that, under all conditions of load on the secondary, the primary carries the full current of the main circuit which is maintained at its normal value by a constant current regulating transformer. The secondary then delivers the same current at much less voltage.

The Type SL transformers are built only with a one-to-one ratio in sizes ranging from 40 watts to 10 kilowatts, the rating being based on a unity power-factor load. They are also made for both aerial and underground construction, the latter being placed in absolutely water-tight tanks. In sizes up to and including four kilowatts the cases are compound-filled. The larger sizes are in oil-filled tanks. All sizes will operate on short circuit indefinitely and the temperature of the coils will not rise more than 75 degrees centigrade above the temperature of the surrounding atmosphere. In the pole type transformer, both primary and secondary leads enter through single porcelain insulators. In the subway type the leads are brought out through wiping sleeves.

All transformers are given an insulation test as follows: 22,000 volts between the primary winding and the secondary winding and core; 2500 volts from the secondary to the primary and core, except on larger sizes which are given two times normal voltage, plus 1000 volts, in accordance with the latest ruling of the American Institute of Electrical Engineers.

Of special importance in series constant current transformers is correctness of ratio. Variations from true ratio, added to possible variations in the primary current, may produce undesirable changes in the intensity or life of the series lamps. Each Type SL transformer is tested for ratio at the factory. When the load is reduced to 80 per cent of its normal rating, the secondary current will not increase more than one per cent above its full load value, with rated primary current and frequency. These transformers are not designed to carry overloads.

GENERAL DATA ON THE TYPE SL TRANSFORMER						
Transformer Output in Kilowatts at Unity Power-factor Load	Secondary Current in Amperes	§Secondary Voltage on Open Circuit	Efficiency 100 Per Cent Load	Primary Power-factor 100 Per Cent Load	NET WEIGHT IN POUNDS ‡INCLUDING OIL	
					Aerial Type	Subway Type
*0.04	6.6	15	81.0	97.5	6	7
*0.10	6.6	38	87.0	97.5	9	9
†0.25	6.6	95	90.0	98.0	15	16
†0.50	6.6	190	92.0	98.0	21	22
†1.00	6.6	380	94.0	98.5	43	44
†2.00	6.6	760	95.2	98.5	61	62
†3.00	6.6	1340	95.8	99.0	96	97
†4.00	6.6	1820	96.2	99.0	140	141
‡5.00	6.6	2650	96.6	99.0	281	500
‡7.50	6.6	3980	96.9	99.0	390	540
‡10.00	6.6	5300	97.2	99.0	470	570

* No protective device is required with this transformer since the open circuit voltage does not reach dangerous values.
† A protective device is incorporated in the cap of subway transformers of sizes from 250 watts to four kilowatts inclusive.
‡ Type SL transformers below five kilowatts are compound filled. The larger sizes are oil-filled.
§ The maximum voltage which can be observed by means of a voltmeter. The peak voltage on open circuit, as shown by an oscillograph, may rise to five times this value, and as a safety measure the use of a protective device is recommended.
The data included in this table are for standard 6.6-ampere, 60-cycle transformers.

PROTECTIVE DEVICES FOR TYPE SL TRANSFORMERS

TYPE SL transformers are operated on loaded series systems and, consequently, if the secondaries become open-circuited, are subjected to sinusoidal excitation which gives a high distorted secondary voltage. When the transformers are of such size that this open circuit voltage becomes dangerous to the insulation or to operators film protective devices should be used. All sizes up to and including 100 watts will operate on open circuit indefinitely without a protective device since the open circuit voltage does not reach dangerous values. The root-mean-square value of open-circuit voltage on the sizes up to and including two kilowatts will not exceed 300 per cent of the full load value, while on the sizes above two kilowatts, it will not exceed 400 per



Subway type protective device for Type SL transformers



Protective device for pole mounting



Film Cutout and holder for protective devices

cent of the full load value, but the peak value, as measured by an oscillograph, may rise to five times the root-mean-square open-circuit value.

Subway transformers from 250 to 4000 watts have a protective device incorporated in their construction. For larger sizes a separate protective device is used which is entirely water-tight and provided with the necessary wiping sleeves for subway construction.

The protective device consists essentially of an arrangement for short circuiting the secondary of the transformer in case the circuit is broken. A pair of clips which would otherwise short circuit the transformer are normally held apart by a renewable disk which consists of soft metal cemented to the two sides of a fiber disk through which a hole is pierced. The thickness of the fiber determines the strength of the air gap which, being protected, is very uniform. When the gap breaks, the metal flows and fills the hole so as to form a short circuit across the transformer. When the clips are removed with the insulating handle to which they are attached, the transformer is short circuited, thus protecting both the transformer and persons who might come in contact with the secondary circuit.

INDIVIDUAL LAMP SERIES TRANSFORMER TYPE IL



*Type IL Transformer for
aerial mounting*

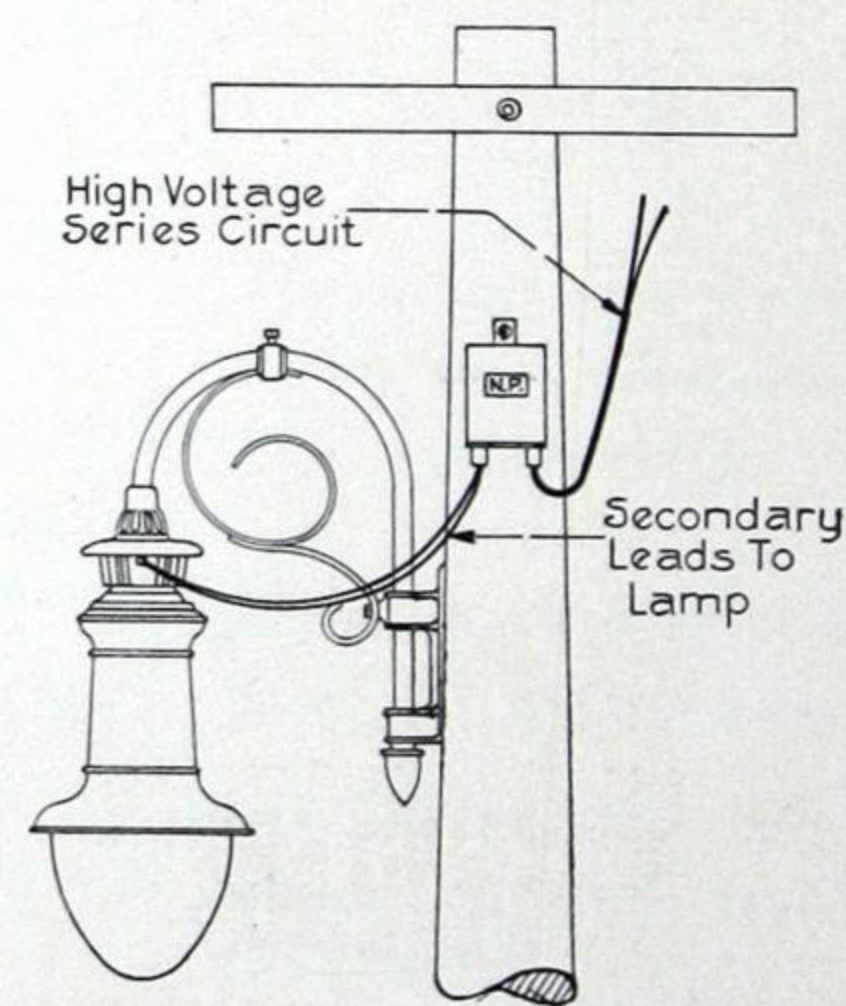
INCANDESCENT lamps in large sizes operate more efficiently at high current than at the 6.6 amperes of standard series lighting circuits. Furthermore, a single large incandescent lamp is much more efficient than a number of small ones. In order to obtain the advantages of the high efficiency of large lamps operating at high current, without changing from the standard 6.6-ampere circuits, a transformer must be used to step up the current. Many ornamental lighting units are equipped with auto-transformers which accomplish this purpose, but those do not insulate the lamp and wiring in the standard from the high voltages of the main circuits.

The Type IL transformer not only steps up the current from 6.6 to 15 or 20 amperes at each lamp but it also keeps the voltage at the lamp low. Low voltage at the lamp saves the expense of high voltage conductors, heavy insulation, and high tension cutouts which materially assist in liquidating the increased expense of an individual lamp series transformer installation; it eliminates "75 per cent of all line troubles" which occur between the pole and the lamp; it greatly increases the safety of an ornamental installation because the poles and lamps are insulated from the high voltage series circuits; and it permits the use of high efficiency lamps in business districts where ordinances are in effect prohibiting high potential wires above the street surface.

The standard Type IL transformer is intended for 6.6 amperes at 60 cycles on the primary. The secondaries are designed with double ratings which permit the operation of two sizes of lamps as indicated in the table on page 30. The secondary leads are tagged to indicate the connections for each lamp.

The Type IL series transformers are designed in three principal types: ornamental pole, subway and aerial. Electrically, they are identical, the basic difference being the mechanical arrangement of bringing out the leads. The windings are entirely enclosed in waterproof steel casings, filled with insulating compound, making a homogeneous unit thoroughly moistureproof.

The ornamental pole type is equipped with detachable couplings on the primary. This connection eliminates the expense of making wiped joints and is also convenient for making tests in event of trouble, as the circuit is readily accessible at the primary terminals and



*Type IL Transformer mounted
on a pole. Three-foot primary
leads on the aerial type trans-
former make splicing in the high
voltage circuit seldom necessary*

may be quickly inspected without the expense of breaking and remaking a wiped joint. The secondary leads are brought out through a right angle joint pipe outlet which is filled with compound forming an absolutely water-tight connection. In cases where the expense of detachable couplings is not warranted, the subway type may be installed in ornamental posts and, if wiped joints are not used, great care should be taken in thoroughly taping over the cable and wiping sleeve on the transformer.

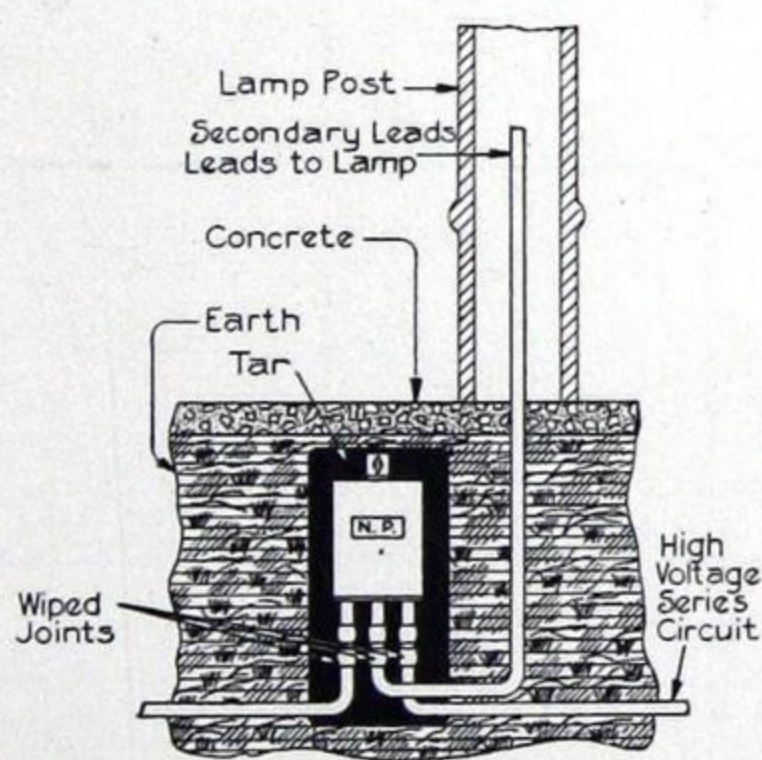
The subway type transformer is built for burying in the ground or for subway service. Both primary and secondary connections should be wiped joints when installed where it is subjected to submer-sion. Wiped joints are not essential when this transformer is used in ornamental poles but care should be exercised in making waterproof taped joints.

The aerial type is designed for mounting on the cross arm of, or attached to, a pole and used in conjunction with pendent Novalux fixtures. This transformer is equipped with 36-inch primary leads and 24-inch secondary leads which are brought out through porce-lain bushings.

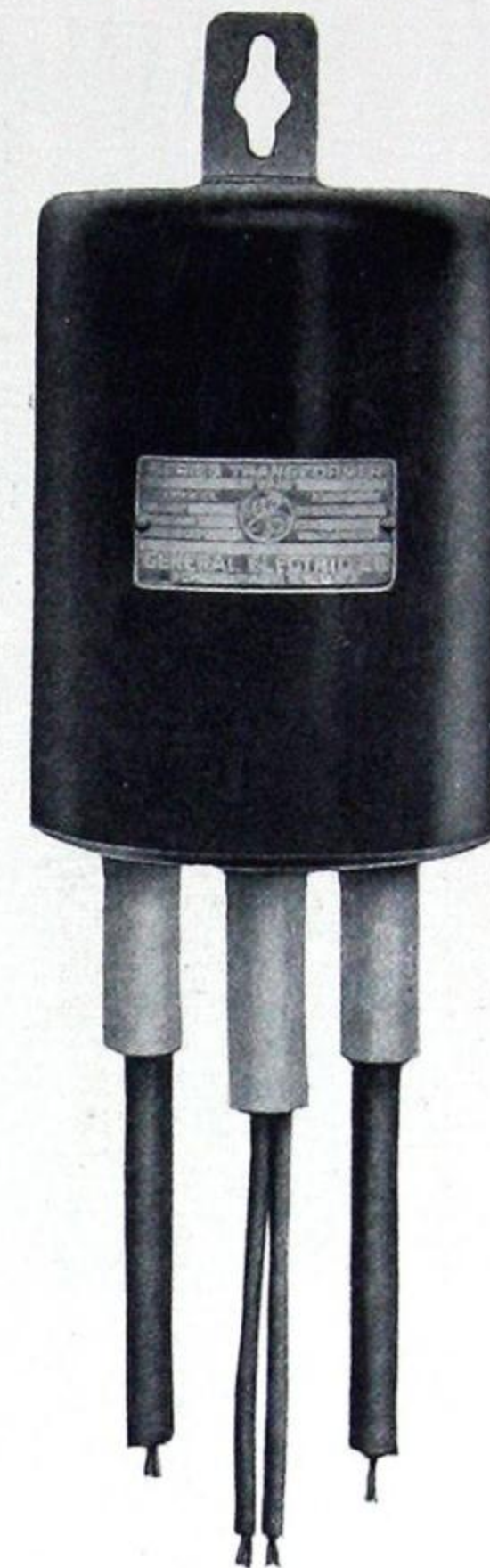
No film cutout is required since each lamp is independent of the others in the circuit. In case of an accident to one or more, the remainder of the lamps on the circuit burn without interruption.

As a protective device for lamps the Type IL transformer has enough reactance to limit line surges and prevent serious injuries. The primary current can go 75 per cent above normal without increasing the secondary current over 45 per cent. Also when the lamp wattage varies between 8 per cent above normal and 20 per cent below normal, the secondary current will not vary more than one per cent with normal primary current and frequency.

A grounding clamp for attaching to the sleeve of the Type IL Transformer may be had. This makes it easy to ground the transformer case and one side of the secondary winding to give additional protection.



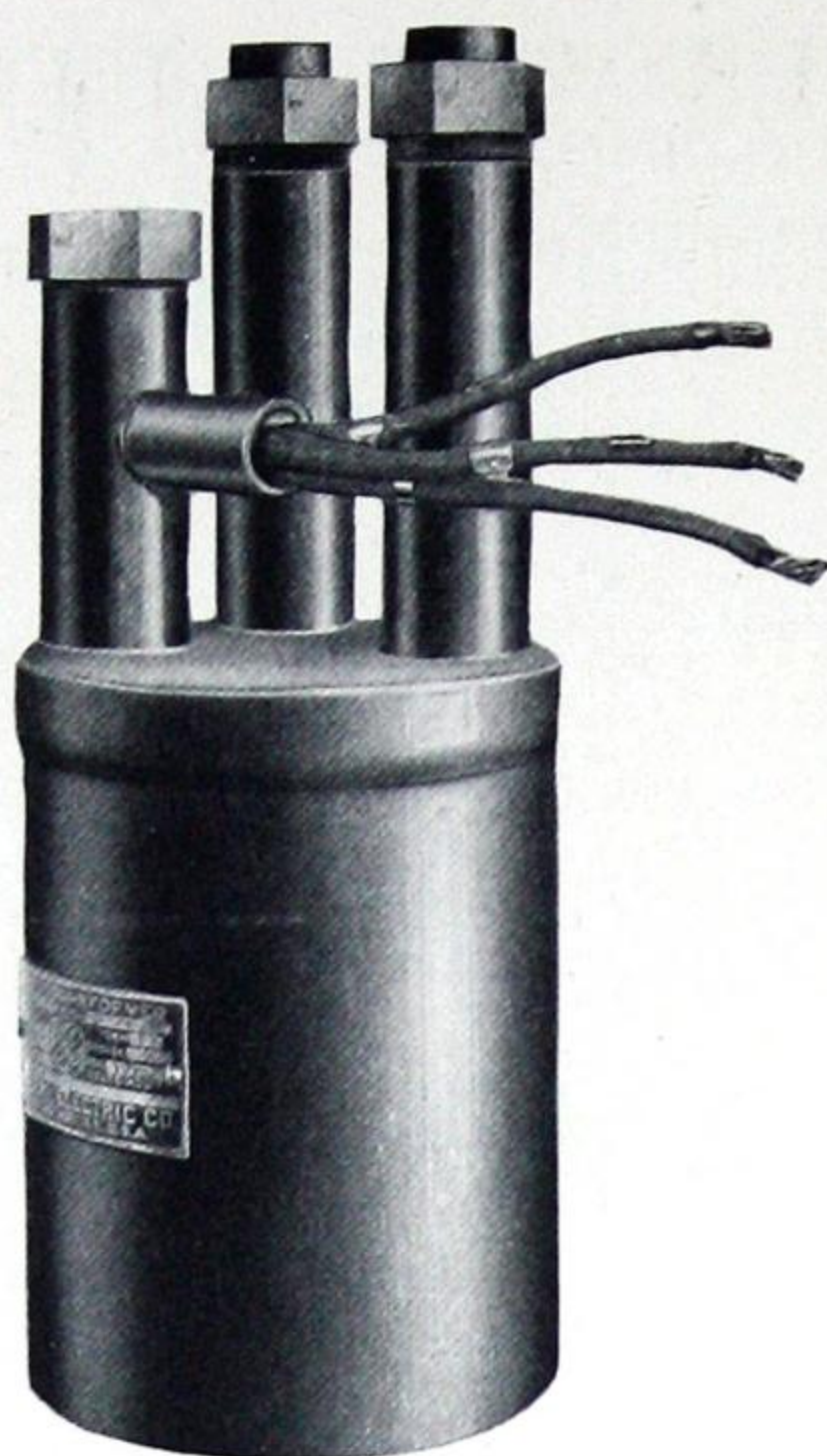
Type IL Transformer buried in the ground. For burying in the ground or subway construction both the primary and the secondary connections should be made with wiped joints to exclude absolutely all moisture



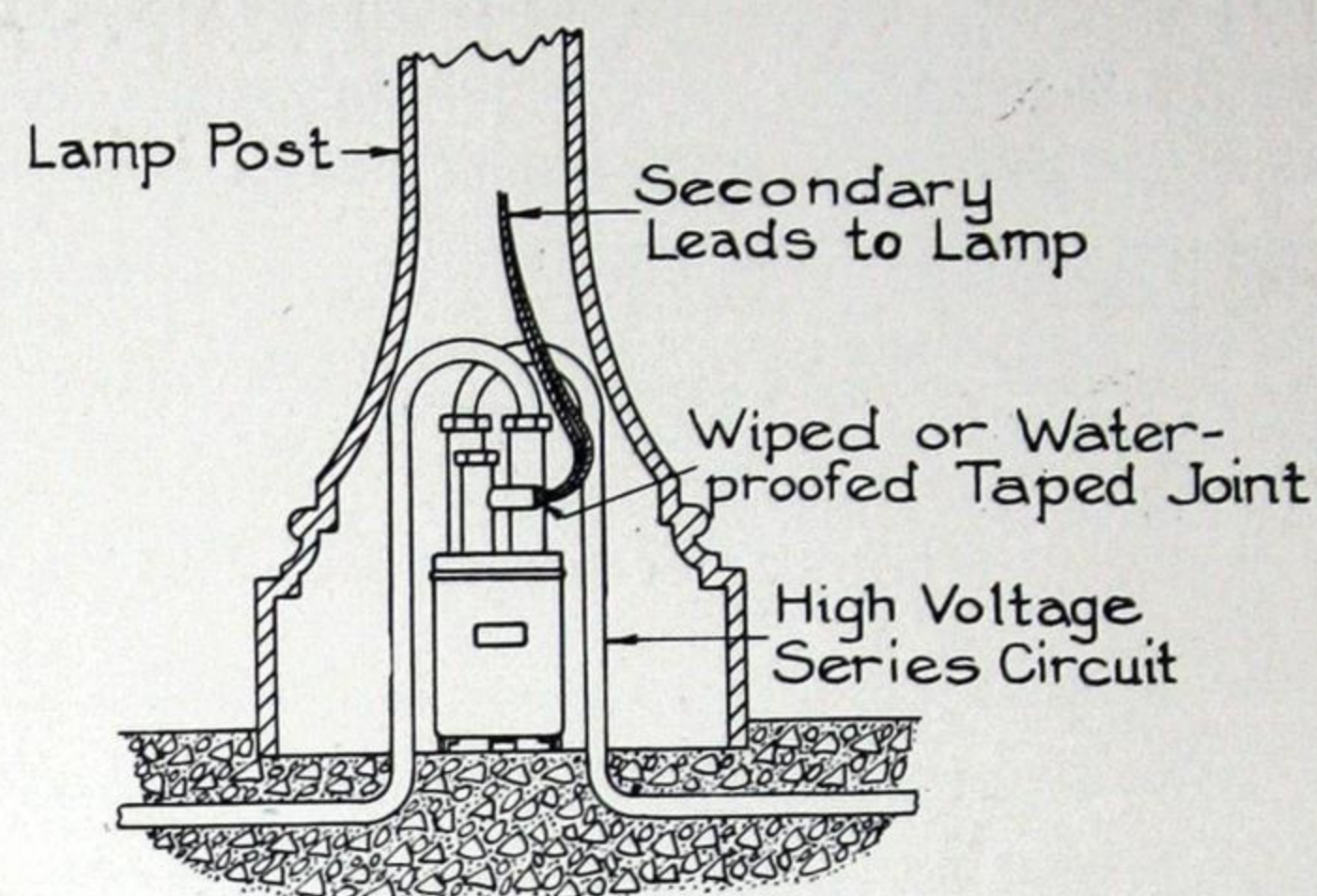
Type IL Transformer for subway mounting

All transformers insulated for 10,500-volt circuits take an insulation test of 22,000 volts for one minute between primary and all parts. All transformers are given an insula-tion test of 1500 volts from secondary windings to metal parts. These tests are in accordance with the rulings of the American Institute of Electrical Engineers.

A Type IL transformer is also made for operating constant potential lamps from a series circuit. This trans-former finds application in traffic control signals and other devices where a low voltage lamp is required and only series current available. It is made in various capacities and will maintain the secondary voltage between 90 and 130 volts.



Type IL Transformer for mounting in an ornamental standard



Type IL Transformer in the base of an ornamental lighting standard. The detachable couplings on the primary leads eliminate the expense of making wiped joints and allow easy access to the primary circuit. The subway type transformer may also be used in ornamental poles if the joints are carefully wiped or taped

It is often desirable to use a Type IL transformer with an ornamental standard on which there are two lighting units. For this service a transformer with a double secondary winding may be used, one winding supplying each lamp. This makes it unnecessary to use film cutouts on the lamps, since the failure of one will not affect the other which is on a separate circuit, yet one transformer does for both lamps.

GENERAL DATA ON THE TYPE IL TRANSFORMER						
*Lamp Rating in Lumens	Secondary Current in Amperes	†Secondary Voltage on Open Circuit	Efficiency 100 Per Cent Load	Primary Power-factor 100 Per Cent Load	NET WEIGHT IN POUNDS	
					Aerial or Subway Type	Ornamental Pole Type
1000 or 2500	6.6	85	91	98.5	15	20
2500 or 4000	6.6 or 15	110	93	98.5	27	27
4000 or 6000	15 or 20	72	93	98.5	27	27
6000 or 10,000	20	117	93	98.5	37	37
10,000 or 15,000	20	170	93	98.5	45	45

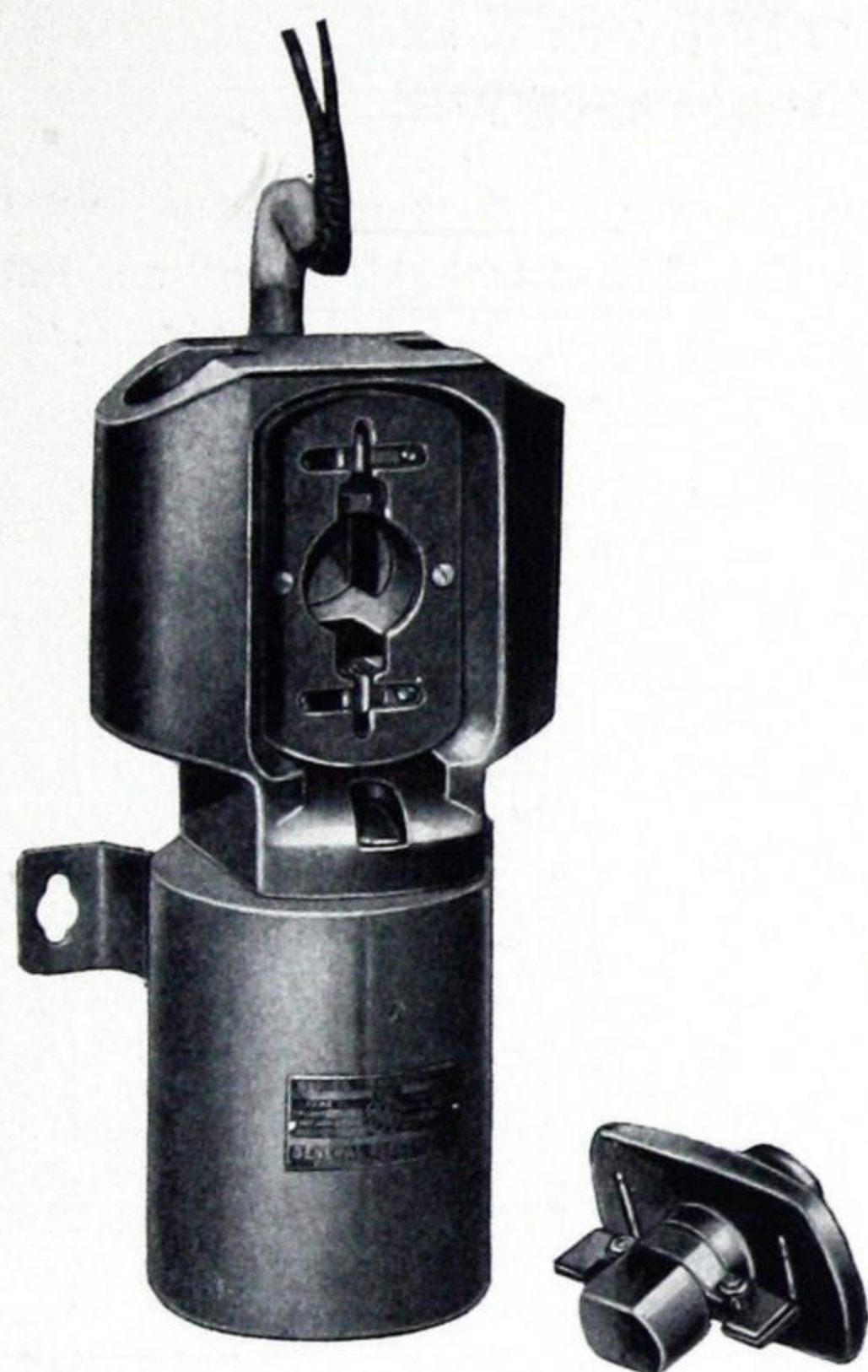
* The transformers for 1000- or 2500-lumen lamps are one-to-one ratio and two secondary leads supply current at 6.6 amperes for either size lamp. The transformers for 2500- or 4000-lumen lamps and those for 4000- or 6000-lumen lamps have three leads from the secondary to supply the larger lamp with the higher current. Transformers for 6000- or 10,000-lumen and 10,000- or 15,000-lumen lamps have only two secondary leads as lamps of these sizes all operate at 20 amperes.

† The maximum voltage which can be observed by means of a voltmeter. The peak voltage on open circuit, as shown by oscillograms, may rise above this value, but the secondary voltage will at no time reach a dangerous magnitude.

The data in the above table are for standard 6.6-ampere, 60-cycle transformers.

INDIVIDUAL LAMP TRANSFORMER WITH CUTOUT TYPE ILC

THE combined cutout and Type IL transformer has been designed for installation where safety and accessibility to the primary circuit are highly desirable. The device includes a Form M absolute series cutout so designed that the leads are imbedded in compound, forming a pot-head connection. The secondary leads are brought



Type ILC Transformer



Type ILC Transformer mounted in the base of an ornamental lighting standard. By removing the plug the lamp is entirely disconnected from the series circuit

out through a goose neck outlet which is sealed with compound to prevent moisture entering the casing.

By removing the plug, the transformer and lamp are disconnected from the high voltage series circuit which is at the same time short circuited. On the face of the cutout box is an insulating plate which prevents accidental contact with live parts, but which permits access to the primary circuit for testing purposes. A special plug with test leads may be had.

The electrical characteristics of the transformer are identical to the standard Type IL. The Type ILC, however, is built primarily for installation in the base of ornamental standards but can be furnished for any series lamp.

TRANSFORMER CAPACITIES

IN the preceding pages all transformer ratings have been given in terms of kilowatt output at unity power-factor. While this is a true and accurate rating, it is of comparatively little significance in connection with street lighting installations until translated into terms of the number of lamps to which any given transformer can supply energy. When, as in the case of series lamps, the rating is given in lumens it is even more difficult to form a conception of the number of actual lamps required to load fully a transformer, especially when they are used in connection with auxiliary series transformers.

The table below gives approximately the number of MAZDA C lamps which the Type RO and RV Transformers will supply with current. In compiling this table it has been assumed that five per cent of the energy is lost in the conductor connecting the lamps. If auto-transformers are used instead of the Type IL series transformers, the number of lamps should be increased by ten per cent for Type RO transformers, and five per cent for Type RV transformers.

CAPACITIES OF CONSTANT CURRENT REGULATING TRANSFORMERS IN TERMS OF LAMPS												
Transformer Output in Kilowatts at Unity Power-factor Load	STRAIGHT SERIES MAZDA C LAMPS OPERATING AT 6.6 AMPERES						6.6 AMPERE LAMPS OPERATING FROM TYPE SL TRANSFORMERS		15- AND 20-AMPERE MAZDA LAMPS OPERATING FROM TYPE IL TRANSFORMER			
	600 Lumens 43.8 Watts	800 Lumens 55.6 Watts	1000 Lumens 68.2 Watts	2500 Lumens 152.4 Watts	4000 Lumens 244 Watts	6000 Lumens 361 Watts	1000 Lumens	2500 Lumens	4000 Lumens 15 Amp.	6000 Lumens 20 Amp.	10,000 Lumens 20 Amp.	15,000 Lumens 20 Amp.
TYPE RV TRANSFORMERS												
5	109	85	70	31	19	13	55	24	17	12		
10	217	171	139	62	39	26	109	49	34	24	15	10
15	325	256	209	93	58	39	163	73	51	36	22	15
20	433	342	278	124	77	52	218	97	68	47	29	20
25	542	427	348	156	97	65	272	122	85	58	37	25
30	650	512	418	187	117	79	326	146	102	71	44	30
35	758	597	487	218	136	92	381	170	119	83	51	35
40	867	684	557	249	155	105	436	195	136	95	59	40
50	1083	854	696	311	194	131	545	243	170	118	73	50
60	1300	1025	836	374	234	158	653	292	204	142	88	61
70	1518	1200	875	436	272	184	763	340	239	166	102	71
TYPE RO TRANSFORMER												
1.0	22	17	14				10					
2.0	43	34	28	12			21					
3.0	65	51	42	19	11		31	14	10			
5.0	109	85	70	31	19	13	52	23	16	11		
7.5	163	128	104	47	29	19	78	35	24	17	10	
10.0	217	171	139	62	39	26	103	46	32	23	14	
15.0	325	256	209	93	58	39	156	69	49	34	21	14
20.0	433	342	278	124	77	52	207	92	65	45	28	19
25.0	542	427	348	156	97	65	259	115	81	56	35	24
30.0	650	512	418	187	117	79	311	139	97	68	42	29

